WORLD FORESTRY SERIES BULLETIN NUMBER TWO

FOREST FERTILIZATION

A Bibliography, With Abstracts, On the Use of Fertilizers and Soil Amendments in Forestry

STATE UNIVERSITY COLLEGE OF FORESTRY AT SYRACUSE UNIVERSITY

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A bibliography, with abstracts, on the use of fertilizers and soil amendments in forestry

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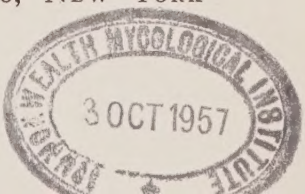

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PREFACE

THE PROSPECT OF INCREASING THE GROWTH OF FORESTS AND BRINGING waste lands into useful timber production by the use of fertilizers and other soil amendments has intrigued silviculturists for almost a century. During the past decade this dream of a few dedicated workers has developed into world-wide interest and activity by both researchers and practicing foresters.

This compilation of the literature on forest fertilization is offered as an aid to the many new investigators in forest soils research and also to the practicing forester to help in evaluating the possibilities of this silvicultural technique for improving site. No claim is made for perfection or completion of coverage, but we feel that it is reasonably accurate, uniform in citation, and includes most publications through the fall of 1956.

In selecting material for inclusion, the principal criterion for citation was the reporting of investigations or observations on the use of fertilizer or nutrient-containing materials (compost, humus, organic residues) to improve the growth or to effect site amelioration for forestry purposes. The principal objective was to report investigations on forest stands or plantations and we have concentrated on this category. Second in importance was the use of fertilizers in forest nursery management. Shade tree and landscape practices have been included because of the overlap of interest and applicability of results but no claim is made for complete coverage in this area of interest. Research investigations on the nutrition of forest trees in greenhouse, pot culture and hydroponics experiments have also been covered, although it has been sometimes difficult to decide where to draw the line in this category.

In including abstracts whenever possible, we feel that the overall utility of this work has been considerably enhanced. Serious effort has been made to secure author abstracts and these have been used in preference to other summations which may have been available. In this regard the helpful cooperation of many active workers in forest tree nutrition is gratefully acknowledged. Dr. Antonin Němec of Prague who is undoubtedly the outstanding contributor to this field, made a most significant effort in providing author abstracts. The very helpful assistance of Dr. C. O. Tamm of Stockholm, Dr. L. Leyton of Oxford and Dr. C. P. VanGoor of Wageningen is also acknowledged and many others too numerous to mention.

When author abstracts were not obtainable, the primary sources for abstracts were Forestry Abstracts, Biological Abstracts, Soils and Fertilizers and the bibliography of Forest Soils Research prepared by Div. VA (Forest and Range Soils) of the Soil Science Society of America. The contributions of these services are gratefully acknowledged.

Citation and abbreviations have been, whenever possible, according to the *World List*, Butterworth, London, 1952. For publications not listed in this source the style conforms to this standard reference work.

Maximum utility of this work by teachers and researchers requires that some type of indexing be provided. To compile a complete index which would have furnished a key to all papers referring to a particular nutrient or practice would have been a monumental task in itself. Moreover, any attempt at complete indexing which fell short of the goal of perfection may have been more confusing than helpful. However, to assist in locating the principal literature on a particular phase of this subject, a partial index is appended and arranged under several subject headings. This index based on the best judgment of the editors refers by number in alphabetical sequence to the important works on the subjects selected. It is evident that many references will be cited under several topics. In most cases, however, reference to a work under a specific topic indicates primary concern with that subject; minor treatment of other topics in this same paper would not be indicated in the index. For example, an important paper on the use of nitrogen and phosphorus fertilizer in pine plantations would be listed under both nitrogen and phosphorus. Incidental observations on potash response by the author would not merit listing under the potash section.

As in any work of this kind, many hands have helped to lighten the load and meet the inevitable deadline. Messrs. Robert Wood and Emmanuel Van Nierop assisted in library research, Dr. Frederick Klaehn and Mr. Emmanuel Van Nierop ably aided in translation, and Mrs. Ruth Newmiller did nearly all of the secretarial work from the beginning of this project.

Special mention is due to Mr. John Waugh, Director of Information of the Nitrogen Division, Allied Chemical & Dye Corporation, who suggested the timeliness of this effort, and who was directly responsible for obtaining a grant from his company to provide financial assistance in this project.

DONALD P. WHITE
ALBERT L. LEAF

Syracuse, Dec. 1956

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INTRODUCTION

In contrast to agriculture, forestry uses fertilizers—outside of the forest nursery—on a very small scale. This is in part due to the fact that agriculture deals with plants that in general have far greater nutritional demands than the unfertilized soils are able to satisfy. The agricultural plants have been gathered from many parts of the world and have been genetically selected and bred to a very high production. The breeding objective has primarily been for greater production of fruits which means high demand for soil nutrients.

Forestry, on the other hand, deals mostly with the natural plants of the forest. Plants that through many centuries by natural selection have been able to utilize the available site to best advantage for survival and development. In forestry the demand is for the stem rather than the fruit. Seeds, branches and roots, which contain the greater proportion of mineral nutrients, are in almost all cases left in the woods. As decomposition of this residue proceeds, essential elements are released and reused by future forest crops.

Forest soils management of today has to a large extent confined itself to economize with the detritus of the forest. This is accomplished by various methods of slash disposal, control of fire, and cuttings conducted in such a manner that the annual leaffall, branch, bark, fruit, and root detritus and residues from cuttings remain in the forest. Furnished with a suitable environment, favorable decomposition results.

Many forest areas, however, have been mistreated. Repeated fires have burned much of the available organic matter; erosion has washed all or part of the topsoil away, and most of the old agricult-

ural areas available to forestry have been depleted for nutrients prior to abandonment. It is on such areas that forest fertilization experiments have yielded the most impressive results. And it is undoubtedly also on this kind of land that forest fertilization will find most practical application.

Most fertilization experiments have been conducted with young forest plants. Only a few have been carried out in middle-aged or old forests on undisturbed forest soils, and many of these have yielded uncertain or no growth response. This may be due to many factors including the crude technique of measuring growth and a common lack of appreciation that basal area alone is a poor measure of site evaluation. Basal area growth of middle-aged and old stands is only to a small extent influenced by site quality and, within certain limits, stocking. It seems likely that fertilization response in older stands will be most pronounced during the period when current growth begins to decline as it does in all middle-aged stands. This occurs earlier for the pioneer species and later for the more demanding tolerant species. The demand at that age seems, as shown by Hesselman, Romell and others, primarily to be for nitrogen.

Only liming has so far penetrated into practice in a few European countries on a fairly large scale; and the objective of adding lime has been as a soil conditioner rather than as an essential element. We may therefore say that, as yet, fertilization of forest trees has not reached practice. In spite of all the research that has been carried out in forest fertilization, as evidenced by this bibliography, there is still an open field ahead.

Svend O. Heiberg
Professor of Silviculture

SCIENTIFIC PERIODICALS

WITH ARTICLES ON FOREST FERTILIZATION

ABBREVIATION FOR CITATION	PERIODICALS
A. R. Long Ashton Res. Sta.*	A. R. Long Ashton Research Station
Abstr. Int. bot. Congr. 7th. Stockh.	Abstracts. International Botanical Congress. 7th. (Stockholm)
Abstr. Int. bot. Congr. 8th Paris	Abstracts. International Botanical Congress. 8th. (Paris)
Acta for. fenn.	Acta forestalia Fennica, Helsingforiae. (Helsinki)
Acta Inst. bot. Acad. Soil USSR.	Trudy Botanicheskogo Instituta Akademii Nauk USSR. (Moscow)
Advanc. Agron.	Advances in Agronomy. (New York)
Agric. Chemic.	Agricultural Chemicals. (Baltimore)
Agric. Monogr.	Agriculture Monographs (U. S. Department of Agriculture) (Washington)
Agricultura, Louvain	Agricultura. Louvain (Louvain)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Agrobiology, Moscow	Agrobiologia (Moscow)
Allg. Forstz.	Allgemeine Forstzeitschrift (München)
Allg. Forst-u. Jagdztg.	Allgemeine Forst-u. Jagdzeitung (Frankfurt a. M.)
Amer. J. Bot.	American Journal of Botany (Lancaster, Pa.)
Amer. Nurserym.	American Nurseryman (Rochester)
Ann. Acad. tchécosl. Agric.	Sborník Československé Akademie Zemědělské (Praha)
Ann. agron., Paris	Annales agronomiques publiées sous les auspices du Ministére de l'agriculture et du commerce (Paris)
Ann. Inst. For. Res. C.S.R.	Sborník Státních Výzkumných Ústavů Lesnických Č.S.R. (Praha)
Annu. Rev. Pl. Physiol.	Annual Review of Plant Physiology. Stanford University (Palo Alto, Calif.)
Arb. dtsch. LandwGes.	Arbeiten der Deutschen Landwirtschaftsgesellschaft (Berlin)
Arborist's News	Arborist's News (Columbus, O.)
Arch. Forstw.*	Archiv für Forstwesen
Aust. For.	Australian Forestry (Canberra)
Bett. Crops.	Better Crops (with Plant Food) (New York)
Black Rock For. Bull.	Black Rock Forest Bulletin (Cornwall-on-the-Hudson)
Black Rock For. Pap.	Black Rock Forest Papers (Cornwall-on-the-Hudson)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Bodenk. u. PflErnähr.	Bodenkunde und Pflanzenernährung (Berlin)
Bot. Gaz.	Botanical Gazette (Chicago)
Bot. Mag., Tokyo	Botanical Magazine (Tokyo)
Branch Pap. For. Res., Lond.*	Branch Paper on Forest Research. Forestry Commission (London)
Bull. Amer. Soil Surv. Ass.	Bulletin of the American Soil Survey Association (Ames, Ia.)
Bull. Bartlett Tree Res. Lab.	Bulletin, Bartlett (Tree) Research Laboratories (Stamford, Conn.)
Bull. Soc. for. belg.*	Bulletin de la Société forestière belgique
Bull. Coll. Agric. Tokyo	Bulletin of the College of Agriculture. Tokyo Imperial University
Bull. Conn. agric. Exp. Sta.	Bulletin Connecticut Agricultural Exepriment Station (New Haven)
Bull. Cornell agric. Exp. Sta.	Bulletin. Cornell University Agricultural Experiment Station (Ithaca, N. Y.)
Bull. For. Dep. W. Aust.	Bulletin of the Forest Department, Western Australia (Perth)
Bull. For. Bur. Aust.	Bulletin, (Commonwealth) Forestry (and Timber) Bureau, Australia (Canberra)
Bull. For. Comm. Lond.	Bulletin of the Forestry Commission (London)
Bull. Gov't. For. Exp. Sta., Tokyo*	Bulletin, Government Forest Experiment Station, Tokyo (Tokyo)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Bull. Indiana Christ. Tree Grower's Ass.*	Bulletin, Indiana Christmas Tree Grower's Association
Bull. Inst. agron. Gembloux	Bulletin de l'Institut agronomique et des stations de recherches de Gembloux (Gembloux)
Bull. Mo. bot. Gdn.	Missouri Botanical Garden Bulletin (St. Louis)
Bull. N.J. agric. Exp. Sta.	Bulletin of the New Jersey Agricultural Experiment Station (New Brunswick)
Bull. Northeast. Wood Util. Coun.	Bulletin, Northeastern Wood Utilization Council (New Haven, Conn.)
Bull. Ohio agric. Exp. Sta.	Bulletin of the Ohio Agricultural Experiment Station (Wooster)
Bull. Soc. for. Belge*	Bulletin, Société forestière de Belge (Brussels)
Bull. Soc. for. Belgique*	Bulletin, de Société Royale Forestière de Belgique (Brussels)
Bull. Tokyo Univ. For.	Bulletin of the Tokyo Imperial University Forests (Tokyo)
Bull. U. S. Dep. Agric.	Bulletin, United States Department of Agriculture (Washington)
Bull. Wis. agric. Exp. Sta.	Bulletin, Wisconsin Agricultural Experiment Station (Madison)
C. R. Acad. Sci. USSR	Doklady Akademii Nauk SSSR (Moscow)
Calif. Agric.	California Agriculture. Progress Reports of Agricultural Research (Berkeley)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Chem. Industr., Düsseldorf	Chemische Industrie (Düsseldorf)
Cir. U. S. Dep. Agric.	Circular, United States Department of Agriculture (Washington)
Coedwigwr.	Coedwigwr, Magazine of the Forestry Society of North Wales
Commun. Inst. for. Finl.	Metsatieteellisen Koelaitoksen Julkaisuja (Helsinki)
Congr. Un. int. Rech. for. Budapest	Congres de l'Union internationale des Institutes de recherches forestières, (Budapest)
C. R. Congr. for. Nancy*	Comptes rendus du Congrès Forestier (Nancy)
Csl. Haj	Československý Haj
Csl. Les.	Československý Les. Kr. Vinohrady (Vinohrady)
Dansk Skovforen. Tidsskr.	Dansk Skovforeningens Tidsskrift (Kjøbenhavn)
Dokl. obsch. Sobr. Ak. Nauk SSSR	Doklady na obshchem Sobranii (Akad. Nauk SSSR) (Leningrad)
Down to Earth	Down to Earth (Dow Chemical Co.) (Midland, Mich.)
Dtsch. Forschung*	Deutsche Forschung
Dtsch. Landw., Berl.	Deutsche Landwirtschaft (Berlin)
Ecology	Ecology (Brooklyn)
Ernähr. Pfl.	Ernährung der Pflanze. Mitteilungen des Kali-Syndikats (Berlin)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Ext. Act. Congr. Luxem.*	Extrait des Actes du Congrès de Luxembourg
Farm Victory*	Chilian Nitrate Educational Bureau, Inc., Farm for Victory
For. Abstr.	Forestry Abstracts (Oxford)
For. Bull. Tokyo Univ.*	Forestry Bulletin, Tokyo University (Tokyo)
For. Chron.	Forestry Chronicle (Toronto, Ont.)
For. Quart.	Forestry Quarterly (Ithaca, N. Y.)
For. Res. India	Forest Research in India (and Burma) (Delhi)
For. Sci.*	Forest Science (Washington)
For. Wrkr. U. S.	Forest Worker, U. S. Department of Agriculture (Washington)
Forestry	Forestry (London)
Forst u. Holz	Forst und Holz (Hannover)
Forstarchiv	Forstarchiv (Hannover)
Forstl. Forsøgsv. Danm.	Forstlige, Det, Forsøgsvaesen i Danmark (Kjøbenhavn)
Forstwirtschaft	Forstwirtschaft Holzwirtschaft (Berlin)
Forstwiss. Zbl.	Forstwissenschaftliches Zentralblatt (Berlin)
Godišnj. Inst. nauč. sumar. Istraž., Sarajewo	Hedeselskabets Tidsskrift (Aarhus)
Hedeselsk. Tidsskr., Aarhus	
Het Thomasmeel*	Het Thomaseel

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Hort. Abstr.	Horticultural Abstracts. Imperial (Commonwealth) Bureau of Fruit Production (Horticulture and Plantation Crops) (East Malling)
Idaho For.	Idaho Forester (Moscow)
Inst. Pap. For. Inst. Oxf.	Institute Paper, Imperial Forestry Institute (Oxford)
Int. Poplar Comm., Madrid*	International Poplar Commission (Madrid)
Intersylva	Intersylva, Zeitschrift der Internationalen Forstzentrale (Berlin-Wannsee)
Iowa St. Coll. J. Sci.	Iowa State College Journal of Science (Ames)
J. agric. Res.	Journal of Agricultural Research (Washington)
J. Amer. chem. Soc.	Journal of the American Chemical Society (Easton, Pa.)
J. Amer. Soc. Agron.	Journal of the American Society of Agronomy (Washington)
J. Aust. Inst. agric. Sci.	Journal of the Australian Institute of Agricultural Science (Sydney)
J. Coun. sci. indust. Res. Aust.	Journal of the Council for Scientific and Industrial Research, Australia (Melbourne)
J. Elisha Mitchell sci. Soc.	Journal of Elisha Mitchell Scientific Society (Chapel Hill, N. C.)
J. For.	Journal of Forestry (Washington)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
J. Jap. For. Soc.	Journal of the Japanese Forestry Society (Tokyo)
J. Minist. Agric.	Journal of the Ministry of Agriculture and Fisheries (London)
J. S. Afr. For. Ass.	Journal of the South African Forestry Association (Pretoria)
J. Tenn. Acad. Sci.	Journal of the Tennessee Academy of Science (Nashville)
J. Wildlife Mgmt.	Journal of Wildlife Management (Menasba, Wis.)
K. Landtbr Akad. Handl. Stockh.	Kungliga Landtbruksakademiens (Handlingar och) Tidskrift (Stockholm)
Korte Meded. Rijksbosch-Proefst.	Korte Mededeelingen het Rijksboschouwproefstation (Wageningen)
Leafl. Ala. agric. Exp. Sta.	Leaflet, Alabama Agricultural Experiment Station (Auburn)
Leafl. For. Bur., Canberra	Leaflet, (Commonwealth) Forestry (and Timber) Bureau (Canberra)
Les. Khoz. Lesoeksp.*	Lesnoe Khoziaĭstvo i Lesoeksploatatsiia (Moscow)
Lesn. Pracé	Lesnická Pracé (Warszawa)
MacMillan Lect. For. Univ. B. C.*	H. R. MacMillan Lectureship in Forestry, University of British Columbia (Vancouver)
Medd. Skogsforskninst. Stockh.	Meddelanden från Statens Skogsforskningsinstitut (Stockholm)
Meded. LandbHoogesch.,	Mededeelingen van de Landbouwhoogeschool (Wageningen)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Mém. Inst. sci. Madagascar	Mémoires de l'Institut scientifique de Madagascar (Tananarive)
Metsät. Aikakausl.	Metsätaloudellinen Aikakauslehti (Helsinki)
Misc. Publ. U. S. Dep. Agric.	Miscellaneous Publications. United States Department of Agriculture (Washington)
Mitt. Forstwirt. Forstwiss.	Mitteilungen aus Forstwirtschaft und Forstwissenschaft (Hannover)
Mitt. schweiz. ZentAnst. forstl. Versuchsw.	Mitteilungen der Schweizerischen Zentralanstalt für das forstliche Versuchswesen (Zürich)
Mitt. StForstverw. Bayern.	Mitteilungen aus der Staatsforstverwaltung Bayerns (München)
Mitt. württemb. forstl. VersAnst.	Mitteilungen der Württembergischen Forstlichen Versuchsanstalt (Stuttgart)
N. Z. J. Sci. Tech.	New Zealand Journal of Science and Technology (Wellington)
Ned. BoschbTijdschr.	Nederlandsch boschbouwtijdschrift (Wageningen)
Norrlands SkogsFörb. Tidskr.	Norrlands Skogsvårdsförbunds Tidskrift (Stockholm)
Occ. Pap. Sth. For. Exp. Sta.	Occasional Papers. Southern Forest Experiment Station (New Orleans)
Ohio J. Sci.	Ohio Journal of Science (Columbus)
Oikos	Oikos. Acta Ecological Scandinavica (København)
Öst. Forst-u. Holzwirtsch.*	Österreichische Forst-und Holzwirtschaft

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Öst. Vjschr. Forstw.	Österreichische Vierteljahrsschrift für Forstwesen (Wien)
Pakist. J. For.*	Pakistan Journal of Forestry
Pamphl. Coll. For. St. Univ. N. Y.*	Pamphlet, College of Forestry, State University of New York (Syracuse)
Pedology, Leningr.	Pochvevedenie (Leningrad)
Penn. For. Wat.	Pennsylvania Forests and Waters (Harrisburg)
Phosphorsäure	Phosphorsäure (Berlin)
Physiol. Plant.	Physiologia Plantarum (København)
Phytopathology	Phytopathology (American Phytopathological Society) (Lancaster, Pa.)
Plant Food Rev.*	Plant Food Review
Plant Physiol.	Plant Physiology (Lancaster, Pa.)
Plant and Soil	Plant and Soil. International journal of plant nutrition, etc. (The Hague)
Pol'ana	Pol'ana (Bratislava)
Potash Rev.*	Potash Review. International Potash Institute. (Berne, Switzer.)
Potasse	Potasse (Mulhouse)
Pracé výzkum. Ust. lesn. ČSR*	Pracé výzkumnich Ustavu lesnickych ČSR
Proc. Ass. Sth. agric. Wkrs.	Proceedings of the Association of Southern Agricultural Workers (Raleigh, N.C.)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Proc. nat. Comm. Fert. Appl.	Proceedings of the National Joint Committee on Fertilizer Application (Washington)
Proc. nat. Comm. Nitrog. Util.	Proceedings. National Joint Committee on Nitrogen Utilization (Washington)
Proc. nat. Shade Tree Conf.*	Proceedings. National Shade Tree Conference (Washington)
Proc. Okla. Acad. Sci.	Proceedings of the Oklahoma Academy of Science (Stillwater)
Proc. Soc. Amer. For.	Proceedings of the Society of American Foresters (Washington)
Proc. Soil Sci. Soc. Amer.	Proceedings of the Soil Science Society of America (Madison, Wis.)
Proc. 3rd. Sth. Conf. For. Tree Improve.*	Proceedings of the 3rd Southern Conference on Forest Tree Improvement
Proc. Va. hort. Soc.	Proceedings of the Virginia State Horticultural Society (Bedford City)
Prog. Rep. Div. For. Biology, Can.*	Bimonthly Progress Report of the Division of Forest Biology, Department of Agriculture, Canada
Publ. Inst. nat. agron. Congo belge: (a) Série sci., (b) Série tech.	Publications de l'Institut national pour l'étude agronomique de Congo belge. (a) Série scientifique, (b) Série technique
Pulp Pap. Mag. Can.	Pulp and Paper Magazine of Canada (Montreal)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Quart. Bull. Mich. agric. Exp. Sta.	Quarterly Bulletin. Michigan Agricultural Experiment Station (East Lansing)
Quart, J. For.	Quarterly Journal of Forestry (London)
Qd. agric. J.	Queensland Agricultural Journal (Brisbane)
Qd. J. agric. Sci.	Queensland Journal of Agricultural Science (Brisbane)
Rapp. Congr. Inst. Industr. agric. 8th.*	Rapports. Congrès International des Industries agricoles. 8th (Bruxelles)
Rec. Inst. Rech. agron. Rép. tchécosl.	Sborník výzkumných ústavu zemědělských ČSR
Rel. Bur. Plant Ind., Dep. Agric.*	Release of the Bureau of Plant Industry, Soils, and Agricultural Engineering (Washington)
Rel. Tenn. Valley Auth. Dep. Agric.*	Release of the Tennessee Valley Authority, U. S. Department of Agriculture (Washington)
Rep. Coun. sci. industr. Res. Aust.	Report. Council for Scientific and Industrial Research. Commonwealth of Australia (Melbourne)
Rep. Dep. Agric. Qd.	Report of the Department of Agriculture and Stock, Queensland (Brisbane)
Rep. Dir. Agric. Fish. For. Hong Kong*	Report, Director of Agriculture, Fisheries and Forestry (Hong Kong)
Rep. Dir. For. Qd.*	Report. Director of Forestry, Queensland

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Rep. E. Malling Res. Sta.	Report of the East Malling Research Station (East Malling)
Rep. For. Bur., Canberra	Report. Commonwealth Forestry (and Timber Bureau (Canberra)
Rep. For. Comm. Lond.	Report of the Forestry Commissioners (London)
Rep. For. Dep. Nigeria	Report. Forestry Department (Administration) Nigeria (Lagos)
Rep. For. Dep. Sudan*	Report of the Forest Department of Sudan
Rep. For. Dep. Tasm.	Report. Forestry Department, Tasmania (Hobart)
Rep. For. Res., Lond.	Report on Forest Research, Forestry Commission (London)
Rep. N.Z. For. Serv.	Report. New Zealand State Forest Service (Wellington)
Rep. Rothamst. exp. Sta.	Report of the Rothamsted Experimental Station (St. Albans)
Rep. sth. For. Exp. Sta.	Report Southern Forest Experiment Station (New Orleans)
Rep. Wattle Res. Inst. Univ. Natal	Report. Wattle Research Institute, University of Natal (Pietermaritsburg)
Rep. Westvaco exp. For.*	Report. West Virginia Company Experimental Forest
Repr. Skogen og Klimaet*	Reprint. Skogen og Klimaet
Res. Bull. exp. For. Hokkaido.	Research Bulletin of the College Experimental Forests, College of Agriculture, Hokkaido Imperial University, Sapparo (Japan)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Res. Bull. Ia. agric. Exp. Sta.	Research Bulletin. Iowa Agricultural Experiment Station (Ames)
Res. Bull. Mo. agric. Exp. Sta.	Research Bulletin. Missouri Agricultural Experiment Station (Columbia)
Res. Notes For. Serv. Qd.*	Research Notes. Forest Service, Queensland (Brisbane)
Res. Notes Univ. Fla. For. Sch.*	Research Notes. University of Florida Forestry School. (Gainesville)
Res. Rep. Coll. Akamatsu.*	Research Report of the College of Akamatsu
Rev. Eaux For.	Revue des eaux et forêts (Paris)
Rev. for. Fr.	Revue forestiére de France (Paris)
S. Afr. J. Sci.	South African Journal of Science (Cape Town)
S. B. dtsch. Akad. Wiss.	Sitzungsberichte der Deutschen Akadamie der Wissenschaften zu Berlin. (Berlin)
SchrReihe forstl. Fak. Univ. Göttingen*	Schriftenreihe der forstlichen Fakultät, Universität Göttingen
Schweiz. Z. Forstw.	Schweizerische Zeitschrift für Forstwesen (Bern)
Sci. Hort.	Scientific Horticulture (Wye.)
Science	Science (New York)
Scot. For. J.	Scottish Forestry Journal (Edinburgh)
Seljacka Knjiga, Sarajevo*	Seljacka Knjiga (Sarajevo)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Ser. Agron. Prod. Phosphate*	Service Agronomique des Producteurs Belges et Luxembourgeois de Phosphate ou Scories Thomas, 47 Cantersteen, Brussels (Brussels)
Shade Tree	Shade Tree (Kearney, N.J.)
Skogen	Skogen (Stockholm)
SkogsvFören. Tidskr., Stockh.	Skogsvårdsföreningens Tidskrift (Stockholm)
Soil Sci.	Soil Science (New Brunswick, N.J.)
Soils and Fert.	Soils and Fertilizers (Harpenden)
Sovietsk. Bot.	Sovietskaia Botanika (Akademii Nauk SSSR) (Leningrad)
Soviet Agron., Moscow	Sovietskaia Agronomiia (Moscow)
Spec. Rep. Hokkaido For. Exp. Sta.*	Special Report. Hokkaido Forest Experiment Station
Sta. Notes cent. St. For. Exp. Sta.	Station Notes. Central States Forest Experiment Station (Columbus, Ohio)
Šumarski List	Šumarski List. Revue forestière croate (Zagreb)
Svensk bot. Tidskr.	Svensk botanisk Tidskrift (Stockholm)
Svenska SkogsFören. Tidskr.	Svenska Skogvårdsföreningens Tidskrift (Stockholm)
Sym. Ann. Staff Conf. Sapparo Branch Gov't For. Exp. Sta.*	Symposia. Annual Staff Conference, Sapparo Branch Government Forest Experiment Station

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Tech. Bull. Minn. agric. Exp. Sta.	Technical Bulletin. Minnesota Agricultural Experiment Station (St. Paul)
Tech. Bull. U. S. Dep. Agric.	Technical Bulletin. U. S. Department of Agriculture (Washington)
Tech. Commun. Bur. Hort., E. Malling	Technical Communications. Imperial (Commonwealth) Bureau of Horticulture and Plantation Crops (East Malling)
Tech. Notes Lakes St. For. Exp. Sta.	Technical Notes. Lake States Forest Experiment Station. (St. Paul, Minn.)
Tech. Notes Wis. Conserv. Dep.*	Technical Notes. Wisconsin Conservation Department (Madison)
Tech. Pap. cent. St. For. Exp. Sta.	Technical Papers. Central States Forest Experiment Station (Columbus, Ohio)
Tharandt. forstl. Jb.	Tharandter forstliches Jahrbuch (Berlin)
Tidsskr. Planteavl	Tidsskrift for Planteavl (Kjøbenhavn)
Tidsskr. Skogbruk	Tidsskrift for Skogbruk (Kristiania)
Tidsskr. Skovvaes.	Tidsskrift for Skovvaesen (Kjøbenhavn)
Tijdschr. ned. Heidemaatsch.	Tijdschrift der Nederlandsche heidemaatschappij (Arnhem)
Timb. Ind., Moscow	Lesnaia Promyshlennost (Moscow)

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Trans. Jap. For. Soc.*	Transactions of the Japanese Forestry Society
Trans. Omsk Inst. Agric.	Trudy Omskogo Instituta Selskogo Khoziaístva imeni C. M. Kirova (Omsk)
Trans. R. Scot. arb. Soc.	Transactions of the R. Scottish Arboricultural Society (Edinburgh)
Trans. Wis. Acad. Sci. Arts Lett.	Transactions of the Wisconsin Academy of Sciences, Arts and Letters (Madison)
Trav. Sta. Rech. Groenendael	Travaux de la Station de recherches de Groenendael
Tree Plant. Notes*	Tree Planters' Notes (Washington)
Trees Mag.	Trees Magazine (Santa Monica, Calif.)
Trop. Agriculture, Trin.	Tropical Agriculture. The Journal of the Imperial College of Agriculture (Trinidad)
Växt-närings-Nytt*	Växt-närings-Nytt (Stockholm)
W. Va. Conserv.*	West Virginia Conservation
Yearb. Agric. U. S. Dep. Agric.	Yearbook of Agriculture. U. S. Department of Agriculture (Washington)
Z. Forst-u. Jagdw.	Zeitschrift für Forst-u. Jagdwesen (Berlin)
Z. PflErnähr. Düng.	Zeitschrift für Pflanzenernährung und Düngung (und Bodenkunde) (Leipzig)
Za sots. sel. Nauku*	Za socialističeskuju Selskochozjajstvennuju Nauku

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

ABBREVIATION FOR CITATION	PERIODICALS
Za social. Zemed.*	Za socialistickě Zemedestvi
Zpr. výzkum Úst. lesn. ČSR*	Zprávy Štatných Výzkumných Ústavov Lesnických ČSR

*Not in *World List*, 3rd Ed. Butterworth, London. 1952.

TERMS AND ABBREVIATIONS

Terms appearing in *Webster's Collegiate Dictionary* and *Concise Oxford Dictionary* are ordinarily used in the text without explanation. The Society of American Foresters Forest Terminology and British Commonwealth Forest Terminology are followed for forestry terms.

The following is a list of abbreviations that commonly occur in the text:

°C. ..... degrees Centigrade
ca. (appr.) about, approximately
cm. ..... centimeter(s)
cu. ..... cubic
cwt. ..... hundred weight

d. b. h. .... diameter-breast-height
diam. ..... diameter
diam. u. b. diameter under bark

°F. ..... degrees Fahrenheit
ft. ..... foot (feet)

g. ..... grams
g. b. h. .... girth-breast-height
gal. ..... gallon(s)

ha. ..... hectare(s)

in.(s). .... inch(es)

kg. ..... kilogram(s)

l. ..... liter(s)
lb.(s). .... pound(s)

m. ..... meter(s)
me. ..... milliequivalents
mg. ..... milligram(s)
ml. ..... milliliter(s)
mm. ..... millimeter(s)
m. p. h. .. miles-per-hour

oz.(s). .... ounce(s)

p.(pp). .. page(s)
ppm. ..... parts per million

S.D.m. .... standard deviation of the mean
sq. ..... square
soln. ..... solution
spp. ..... species

vol. ..... volume
yr.(s). .... year(s)

m. ..... micron

SOURCE OF ABSTRACTS

A ..... Author

a ..... from Forest Soils Research – Forest & Range Soils Div., S.S.S.A.

aA ..... from Forest Soils Research – Forest & Range Soils Div., S.S.S.A. (Author abstract)

fa ..... Forestry Abstr.

faA ..... Forestry Abstr.– Author Abstract

GKV .... G. K. Voigt

L. ..... A. L. Leaf

W. ..... D. P. White

Van ..... E. Van Nierop

S-F ..... Soils and Fertilizers

Ba ..... Biological Abstr.

BaA ..... Biological Abstr.– Author Abstract

Ca ..... Chemical Abstracts

Ley. ..... L. Leyton

BIBLIOGRAPHY

ADDOMS, R. M. 1

1937 Nutritional studies on loblolly pine. Plant Physiol. 12: 199-205. L

Loblolly pine seedlings were grown successfully in sand cultures for periods up to 29 months. They proved capable of utilizing nitrogen in the form of either nitrate or ammonium—the former more successfully in acid reaction, the latter more successfully in a more nearly neutral reaction. Mycorrhiza were not formed. Many plants of both the nitrate and the ammonium series showed, at times, a yellowing of leaves that may have been caused by an insufficient quantity of nitrogen. Apparently similar conditions were observed in soil cultures and to a lesser degree in the field.

In light of these experiments the author feels justified in pursuing the study of mineral deficiencies in loblolly pine by the use of sand cultures, employing either nitrates or ammonium salts as sources of nitrogen.

AFANASIJEV, D. 2

1951 a (Agricultural techniques in forestry). Godišnj. Inst. nauč. šumar. Istraž., Sarajevo. 1951: 147-187. (Croat. w/Russian and English summaries) fa

In 1937 an experimental area for studies on forest improvement was established by a group of Jugoslav foresters near Sarajevo, where the growing season is relatively short. The soil, sterile and of poor physical structure, was carefully cultivated in small plots

and manured with various fertilizers, the moisture conditions improved by drainage, and the harmful effect of winds reduced by shelterbelts. An important factor was the introduction of shrubs and low trees, mostly *Maclura*, *Mahonia*, *Elaeagnus*, *Rubus*, and *Ribes*, to nurse the forest crop. The planting density varied from 4166 to 25,000/ha. The main trees tested were: *Picea*, *Quercus*, *Ulmus*, *Juglans*, *Fraxinus*, *Tilia*, *Castanea*, *Larix*, *Acer*, *Pinus sylvestris*, *Aesculus hippocastanum*, and *Pinus nigra*. The fertilizers used were: horse and sheep manure; Nitrophoska; $CaCN_2$; Caurea; Chilean saltpeter; $CaCO_3$; bone meal; horn meal; K salts; coal dust from the Zenicki mines, and mixtures of trace elements; B, and Mn, with aspirin (?). Some of the results, presented in tables and a graph, are listed below: in 4 years *Tilia* control plants reached an average height of 0.78 m., compared with 5.86 m. for deep treatment with animal manure + $CaCN_2$; a *Quercus* control was 0.96 m. high, against 6.65 m. for animal manuring; a *Larix* control was 1.12 m. after 5 years, against 5.81 m. for animal manuring. Similar figures for *Ulmus* were 0.47–4.75 m. and 1.13–5.76 m. in two series of experiments; for *Fraxinus*: 0.87–6.83 m.; for *Picea*: 0.48–3.00 m.

Afanasijev, D. 3

1951 b (Experiments in rooting *Sequoia gigantea* cuttings). Godišnj. Inst. nauč. šumar. Istraž., Sarajevo. 1951: 211-219. (Croat. w/Russian and English summaries) fa

Just before World War II, *S. gigantea* was grown from seed at the forest experimental station near Sarajevo. The seeds were steeped in water at 25° C. for 60 hours, then drained, mixed with dry sand and carefully watered. After sowing, the seeds were covered with dry leaves, and, after germination, kept in half-shade. The best sowing time was May, as low temperatures prolong the germination period and increase the danger from fungi, insects, and birds. The sowing patches should be cultivated to a depth of 30-35 cm. and manured with compost or stable dung, the manure/soil proportion being 1:1. Daily watering is required for both seeds and seedlings. Germination of the seeds used (2 years old) was 3.7%. After 4 months, the seedlings were 6-15 cm. high (average 10 cm), and overwintered without a single casuality. Next spring the plants were pricked out, and grew to a height of 38-56 cm. (average 47 cm.). They were manured in spring and summer with N-P-K fertilizers, and surface cultivated after each rain. Late in July, one-half of the

plants were transplanted into final sites, both manured and non-manured, at various aspects and altitudes (600-930 m.). About 40 plants were treated with "mineral auxinbiocatalysts" (probably trace elements?), responding only after 62 days. Height growth after a year averaged: controls, 28 cm.; on cultivated site, 56 cm.; cultivated and "auxin" treated, 82 cm. One of the "auxin" treated plants was 2 m. high at the end of that year (1940?). Only 65 out of 264 *Sequoia* plants survived the war, the taller ones having been felled. After ten years, the control trees averaged 1.60 m. high (clayey soil on rock sub-stratum); the trees on cultivated and manured sites, 4.50 m. (d.b.h. 9 cm.) and the "auxin" treated, 9.60 m. high (d.b.h. 20 cm.). Trees of similar age elsewhere had dimensions as follows: in California, height 3.80 m., d.b.h. 8 cm., Crimea (U.S.S.R.) height 3.10 m., d.b.h. 7 cm. The 9.6 m. high *Sequoia* began to bear cones in 1951, i.e., in the 11th year(?), the usual fruiting age in California and the Crimea being ca. 40 years. The method adapted in the same experimental area for propagating *Sequoia* (and *Chamaecyparis lawsoniana*) by (root and branch) cuttings is also described in detail, and the role played by trace elements is again stressed.

AFANASIJEV, D. 4

1951 c (Establishment of fast growing stands). Šumarski List 75: 387-392. (Croat.) fa

A brief account of experiments made by a group of Yugoslavian foresters and the Forest Experiment Station near Sarajevo. From 1940 certain compounds of trace elements, e.g. B, Mn, etc. with nitrate N and P_2O_5 were used to stimulate growth, with the following results: (1) a 3.20 m. high oak seedling in three months from sowing; (2) an annual height increment of 1.30 m. for a two-year-old *Picea abies*, and of 1.60 m. for a seven-year-old *Fraxinus excelsior;* (3) a *Sequoia gigantea* given trace elements only once, at planting 1940, was in 1950 a tree 10 m. high and 33 cm. d.b.h., and had begun to bear cones. These stands were cut during the war, and the paper on them, which should have appeared in 1941, was lost. A detailed communication will be published shortly.

AFANASIJEV, D. 5

1952 (Fast growing forests. Methods of raising fast growing forests). Seljacka Knjiga, Sarajevo. 277 pp. (Croat. w/ Russian summary)

AIRD, P. L. 6

1956 Fertilizers in forestry and their use in hardwood plantation establishment. Pulp Pap. (Mag.) Can. 57: 376, 379-381, 384. A

Several specific uses of fertilizers in forestry are briefly mentioned, while the use of fertilizers for hardwood plantation establishment is treated in more detail.

The results from a factorial experiment to determine the effect of different combinations of levels of tillage, fertilization, and chemical inhibition of herbaceous vegetation on growth of Raverdeau poplar are discussed.

These results are:

1. In no case did the chemcial inhibition treatments increase growth of the trees, while they did significantly decrease growth on the tilled plots.
2. The effect of fertilizer or tillage treatments on increasing growth were highly significant.
3. Deep fertilizer was significantly better than broadcast fertilizer with respect to volume growth increment.
4. Deep fertilizer resulted in a significantly greater volume growth on tilled than non-tilled plots.
5. One ounce of 10-10-10 fertilizer applied deep was near optimum for first year response on tilled plots.
6. The fertilizer applications were not sufficiently heavy on the non-tilled plots to counteract the nutrient competition by herbaceous vegetation.
7. Competition by herbaceous vegetation not only reduced the growth rate of trees, but also reduced their season of terminal growth.
8. Deep fertilization at planting may eliminate the expensive tillage procedure and yet result in successful hardwood establishment.

ALBERT, R. 7

1936 Ein nachhaltig wirksamer Forstdüngungsversuch (A long-lasting and effective forest fertilization experiment). Forstarchiv 12: 158-162. Ba

With the idea of having 1 application of fertilizer last through an entire rotation, crushed basalt was applied at the rate of 100 cu.

m. per ha. on poor soils, exhausted by litter removal, in Niederlansitz, in 1905. 1-0 pine seedlings were planted in 1907. At first there was little difference in growth between seedlings on treated and untreated areas, but after the 6th year the difference was noticeable. At 23 years of age the timber volume on treated plots was 4-5 times that on untreated plots, and much greater than on plots treated with lime, peat, or Kainit.

ALBERT R. 8

1938 Untersuchungen über die Verwendbarkeit von Gesteinsabfällen verschiedener Herkunft und Art zur Verbesserung geringwertiger Waldböden (On the use of fine debris from stone quarries for the improvement of poor forest soils). Forstarchiv 14: 229-240. fa

Basaltic stone debris increased the fertility of poor forest soils. The immediate and lasting effect is ascribed to the chemical nutrients made available, the addition of active mineral colloids, the neutralizing effect of acid humus and the action of traces of such elements as iodine, fluorine, boron, manganese, and copper. The stone debris studied were sands (0.2-2 mm.) and "meals" (below 0.2 mm.). Their chemical examination by ordinary analysis and electrodialysis gave results differing widely according to their localities of origin. The debris of diabase was found to have a similar fertilizing effect.

ALBERT, R. 9

1940 Untersuchungen über die Tiefenwirkung des Vollumbruches und der Basaltdüngung (Investigations on the effect of complete plowing and basalt fertilizing at various depths in the soil). Forstarchiv 16: 231-232. fa

Data are given on the distribution of bases, acids, Ca, K, Na, and P_2O_5 at various depths up to 50 cm. in waste land, land plowed but unfertilized, and land plowed and fertilized with basalt grit. The plowed and unfertilized land was poorer in all constituents named except P_2O_5. All constituents were much increased by the fertilizer treatment.

ALBERT, R. 10

1948 Neudammer forstliches Lehrbuch. I. Lieferung (Neudammer forestry text book. I ed. K. Rubner (ed.) pp. 53-100. Neumann, Berlin.

ALDRICH-BLAKE, R. N. 11

1932 The influence of nutrition on the relative root and shoot development of forest tree seedlings. Forestry 6: 40-52. L

Seedings of most conifers, and of at least one broadleaved tree, respond to increase in the supply of nitrogen by a decrease of relative root weight. Indications are that phosphates and potash may similarly depress relative root weight, but we have no data from sand culture experiments with forest-tree seedlings. It is assumed that a plant with a relatively light root will be less drought resistant and less tolerant of moving than a plant with a relatively heavy root.

From the practical standpoint the best criterion of the drought resistance of nursery stock is the percentage survival of such stock when it is transplanted or planted out in the forest. The value of manurial treatments in the nursery should therefore be assessed by their influence on the survival and growth of plants after moving.

ALLEN, R. M. 12

1953 Release and fertilization stimulate longleaf pine cone crop. J. For. 51: 827. A

The following four treatments were used to test the effects of release and fertilization on the cone production of second-growth longleaf pine; release, fertilization, release and fertilization, check. The fertilized trees received applications of 5-15-5 fertilizer, the amount varying with their diameter. In release treatments, all dominant, codominant, and intermediate trees were removed from a radius of 17 to 20 feet around the sample trees. The average annual cone production in third and fourth years after initial treatment was 1.3 cones per check tree, 6.9 per released tree, 13.5 per fertilized tree, and 16.7 for trees both released and fertilized.

ALLEN, R. M. and T. E. MAKI 13

1955 Response of longleaf pine seedlings to soils and fertilizers. Soil Sci. 79: 359-362. A

Seedlings of longleaf pine (*Pinus palustris* Mill.) were grown in pots of three different soils: a sandy soil, an eroded soil, top soil. Three fertilizer treatments were used with each soil: control, nitrogen, NPK. After one year the seedlings were lifted and a portion were planted in sand in a greenhouse for a drought test. The study indicated that : 1. Longleaf seedlings grown for a year in different soils can differ not only in green weight but also in ability to sur-

vive after transplanting. 2. The survival of transplanted longleaf seedling of the same average green weight can vary with the medium in which they were grown. 3. Longleaf seedlings grown on these soils do not respond to the addition of nitrogen alone in their first year but do respond to NPK fertilizer.

ALLISON, F. E. AND M. S. ANDERSON 14

1951 The use of sawdust for mulches and soil improvement. Cir. U. S. Dep. Agric. 891. 19 pp. BaA

The available information on the more practical aspects of sawdust decomposition, effects on plant growth, and best methods of utilizing it in agriculture is discussed. Sawdust seldom contains appreciable quantities of toxic substances and has slight effect on soil reaction. If used as a mulch or mixed with the soil it does, however, decrease available soil N as do other low-N crop residues. Approx. 24 lbs. of N is required to counteract the nitrate depleting effect of a ton of most kinds of dry sawdust. Since sawdust may also slightly reduce available P, at least initially, small additions of this element are often needed. Sawdust may be used satisfactorily as a mulch, as a bedding material, in compost, or be applied directly to the soil if supplemental N and P are also added. Under all these conditions sawdust is converted into humus that differs little from that formed from the residues of farm crops.

ALTEN, F. AND W. DOEHRING 15

1952 Die Düngung in der Forstwirtschaft (Fertilization in forestry). Z. Pfl.Ernähr. Düng. 59: 145-157.

For reasons of demand, timber value has risen more than that of agricultural products. German experience in the last 30 years has proved that the structure and nutrient status of poor, acid podzolized soils can be rapidly improved by fertilizing and appropriate cultivation.

Exchange acidity must be eliminated, but overliming unfavorably affects uptake of K and especially P; on mineral soils the most important species show best NPK uptake, growth and root development at pH 5 or above. Liming should be done in the wet season and on the richer sites first; appropriate times include that of cultivation for new planting, 6-8 years after planting, at the start of natural regeneration, or 10-20 years before regeneration, if the decomposition of raw humus is desired. The nutrient requirement of

a stand is greatest at the time of the greatest production of brushwood, i. e., for pine, spruce and beech, at 20, 30 and 40 years of age, respectively, or later on poor soils. Except for N, the yearly nutrient uptake is smaller than for agricultural crops. Considerable nutrient loss, apart from that due to timber removal, occurs in clear-felled areas by leaching and erosion of nutrients mineralized from the litter, in the leaf constituent of which the nutrients mainly occur. Clear felling is particularly exhausting to the poorer soils.

NPK fertilizing is important to nursery plants, new plantings and older stands showing poor growth. 100-200 kg./ha. K_2O+75-150 kg. P_2O_5 as basic slag or Rhenania phosphate should be given as storage fertilization for the nursery. After 3 years, half these amounts may be given. On light sandy soils 40-60 kg. K_2O should be given yearly. K sulphate is much better than chloride for young plants. 20-50 kg. N, or less when green manure or dry peat rich in needles has been plowed in, should be given.

For the forest stand and new plantings a storage fertilization should be given in autumn at about the time of soil preparation. The K_2O application should be 150-200 kg., varying with the adsorptive capacity of the soil. On light sands the K_2O should be broadcast at the rate of 20-25 kg. every second year in spring. On exchange-acid soils liming should be done before K is applied. On podzolized soils low in Mg, KMg sulphate should be used. 6-8 kg./ha. basic slag should be worked in as storage fertilizer. N is often mobilized by careful liming, which also decreases the SiO_2, Al and Mg uptake of leaves and wood. On light sands 10-15 kg./ha. N per year as calcium ammonium nitrate should be given.

NPK applied to 3-year-old pines on very light sand greatly increased wood and root growth over the 5 years of the experiment.

ANDERSON, W. L. 16

1930 A case of "damping off" induced by the use of woodashes as a manure on seedbeds. Scot. For. J. 44: 7-16.

ANDO, A. 17

1952 (On the effects of fertilization on the nutrient contents of sugi (*Cryptomeria japonica* D. Don.) yearling seedlings). For. Bull. Tokyo Univ. 43: 91-100. (Japanese)

Samples were taken monthly from seed beds under three different nutrient levels. At the end of the growing season, the content of

each element in the dry matter was within the following limits: ash 6-6.5%, N1.2-1.8%, P 0.3-0.4%, K 1.5-1.7%, Ca 1.1-1.4%. The change in composition according to the stage of growth was more marked than the effect of the quantity of fertilizer given. The percentage of Ca varied the least, and difference in nutrient contents due to difference in fertilizer application was the least in October. Application of fertilizers caused changes in the distribution of nutrient elements in the roots.

ANDO, A. AND T. HUKASAKU 18

1953 (The effect on the growth of Sugi (*Cryptomeria japonica*) one year seedlings of increasing application of fertilizers). For. Bull. Toyko Univ. 44: 15-22. (Japanese w/English summary) fa

In a series of experiments at the Tanasi and Koibuti nurseries, each of the elements, N, P, or K was applied at 0, 10, to 20 g./sq. m. with a fixed amount (10 g./sq.m.) of the other two. Less seedling growth occured when one element was lacking, especially N at Tanasi and K at Koibuti; also when 20 g. of one element was applied, decrease in growth being greatest for the higher amount of K and least for that of N. The weight/length ratio of the seedlings increased with higher soil fertility and the top/root ratio with increasing amounts of N. In another series, where N was applied at rates of 0, 5, 10, 20, 40, and 60 g./sq.m., seedling growth increased with increasing N to 20 g. and then decreased. The maximum content of N in the seedlings was found at 40 g., being 1.67% for the whole plant and 1.83% for the shoot. N contents in the root were lower than in the shoot, remaining at a nearly constant level of about 1% with applications over 10 g. Relationships between weight and N content in seedlings suggested that the optimum application was 20 g. Utilization of N was highest for an application of 5 g., with a coefficient of absorption of 42% as against 15% for 20 g.

ANDREENKO, S., L. UDALOVA, AND B. LEITZINA 19

1950 (The first year growth of oak seedlings in relation to conditions of mineral nutrition and treatment with growth activating substances). Dokl. obsch. Sobr. Ak. Nauk S.S.S.R. 73: 1061-1064. (Russian language)

ANDREWS, L. K. 20

1941 Effects of certain soil treatments on the development of loblolly pine nursery stock. J. For. 39: 918-921. faA

Soil treatments consisting of Nitro Humite, commercial fertilizer (4-8-4), cotton seed meal, sandy clay loam soil introduced 5 in. under the soil surface, commercial fertilizer(4-8-4), plus sandy clay loam, peat worked 4 in. into the soil, peat plus commercial fertilizer (4-8-4), and peat plus cotton seed meal were applied before seeding to test their effect in improving sandy soils of low productivity for producing well developed 1-year old planting stock. The results indicate that the addition of a finer-textured soil (preferably turned under to form a B horizon) or of organic matter will improve the physical character of sandy soil and stimulate pine seedling growth significantly. Root-shoot ratio by weight is reduced but a root system with a large number of small branching rootlets develops in these media. Concentrated fertilizers with a high phosphorus content tend to increase root-shoot-ratios. Readily soluble fertilizers appear to leach through sandy soils rapidly and therefore are most efficient when applied a few weeks after seed germination. Apparently the most desirable planting stock will be produced when both organic material and concentrated fertilizer containing a high percentage of phosphorus are added to sandy soil.

ANONYMOUS 21

1947 Miscellaneous methods of fertilizer application. Soils and Fert. 10: 117-122. fa

Various methods of applying fertilizers have recently been developed, and the literature on them is here reviewed. The following methods are described: Injection into the soil, injection into the plant, application in solution and in irrigation water, briquettes and "nests", coating seed with fertilizer, and distribution of liquid manure.

ANONYMOUS 22

1953 a Resultats d'essais de fumure avec phosphate Thomas sur épicéa pendant une période de 44 ans à Sart-lez-Spa dans la Fagne Richehomme (The results of manuring trials with basic slag on spruce during a period of 44 years at Sart-lez-Spa in the Fagne Richehomme). Sér. Agron. Prod. Phosphate. 7 pp. fa

Report on an experiment started in 1909 to determine the effect of various fertilizer treatments at the time of planting spruce on an acid *Calluna* heath soil. The treatments were: (1) liming at the rate of 2500 kg./ha. after trenching; (2) as (1) but 5000 kg./ha.; (3) controls; (4) basic slag applied in planting holes at a rate of 1500 kg./ha.; (5) Ca phosphate broadcast at a rate of 3500 kg./ha. after trenching; (6) controls; (7) liming at a rate of 6000 kg. ha. after trenching; (8) as (7) but 9000 kg. ha.; (9) basic slag broadcast at a rate of 1500 kg./ha. after trenching; (10) controls. Data are given for g.b.h. and vol./ha. (including thinnings) in 1948 for all treatments. Treatment (2) gave best results, closely followed by (4) and (8), with the rest a long way behind. Treatment (4) also gave superior height growth in the early stages. It is to be noted that the broadcast application of basic slag gave results much inferior to application in planting holes.

ANONYMOUS 23

1953 b Le phosphate Thomas en silviculture (The use of basic slag in forestry). Ser. Agron. Prod. Phosphate. 40 pp. fa

Deals for the most part with the Sart-lez-Spa experiment in fertilizing spruce but also gives some notes on the effects of applying basic slag at time of planting to fruit trees and poplars.

ANONYMOUS 24

1953 c A bibliography on the application of plant nutrients by leaf spraying. Soils and Fert. 16: 246-262.

ANONYMOUS 25

1954 Fertilizer treatment in young eucalyptus plantations. Rep. Dir. Agric. Fish. For. Hong Kong 1954: 67 pp. fa

Eucalyptus plantations in Hong Kong usually go into check soon after planting, but respond immediately to small applications (½-1 oz. per plant) of $(NH_4)_2SO_4$ and may reach a height of 3-4 ft. by the end of the growing season with no further treatment. These bigger trees also survive the winter better and resume growth more vigorously the next year.

ARMSTRONG, N. 26

1949 Fertilization practices. Arborist's News 14: 85-90.

Armstrong, N. 27
1950 Liquid fertilization of shade trees. Arborist's News 15: 129-134.

Auchter, E. C. 28
1932 Conditions resulting in increased drought injury and care of drought-weakened trees. Proc. Va. hort. Soc. 37: 205-212. a

Recommends application of nitrogenous fertilizers to drought injured trees.

Auerochs, G. 29
1940 Beurteilung des Kalkbedarfes von Waldböden im mittelfränkischen Keupergebiete (Lime requirements of forest soils in red marl regions of central Frankonia). Forstwiss. Zbl. 62: 266-283.

Australia Council for Scientific and Industrial Research. 30
1947 Fertilizer experiments in pine plantations. Rep. Coun. sci. industr. Res. Aust. 1946-1947. 21.

Australian Forestry Bureau 31
1946 Physiological troubles of *Pinus radiata*. Rep. For. Bur. Canberra #8.

Auten, J. T. 32
1945 Response of shortleaf and pitch pines to soil amendments and fertilizers in newly established nurseries in the Central States. J. agric. Res. 70: 405-426. L

Efforts were made to determine mineral nutrient requirements and deficiencies, and to devise effective methods of amending and fertilizing soils and adjusting soil acidity in three Forest Service nurseries producing shortleaf pine and pitch pine. Fertilizer treatments included application of N, P, K, peat, lime, minor elements, and soybean meal in various forms, concentrations, and combinations. Results were based on seedling density, height in the first and second year, and root and top lengths and weights in the second and third year. Generally, acid-treated peat had a beneficial effect on both density and height. Increase in alkalinity due to limestone

treatment resulted in lower seedling density. Height growth response to phosphatic fertilizers was more pronounced in soil at pH 4-6 than at pH 8. Seedling density varied inversely with quantity of phosphorus applied. Generally, the response to minor element treatment was nil. No form of potassium tested stimulated height growth. Nitrogen applied at seedling time, in all forms tested, greatly lowered seedling density. The nurseries were located at Chillicothe, Ohio, Vallonia, Ind., and Licking, Mo.; the first two are on sandy alkaline soils, the last on silt loam slightly acid soils.

AUTEN, J. T. 33

1956 Soil site reconnaissance of Dare County, North Carolina. Rep. Westvaco exp. For. NC-1 (1955). A

Fertilizer tests of two years duration with potassium, copper, zinc, boron, and chromium salts, and with phosphorus at treble super phosphate on planted slash and loblolly pines and on Atlantic white cedar; and a short time test of nitrogen as sodium nitrate on natural stands of pond pine were made on North Carolina coastal organic soils.

Comparatively low mineral content of the soil indicated nutrient deficiencies; but no significant measured differences in height growth of fertilized and unfertilized planted pine stock were observed, nor was any change in the yellowish green color of pond pine needles observed after nitrate nitrogen had been applied to the soil surface.

Analyses for total potassium, phosphorus, and nitrogen in soil supporting good and poor natural pond pine stands failed to show any significant differences. The soil under poor stands was as good as that under moderately good stands.

All soils tested spectroscopically were found not deficient in calcium, magnesium, iron, phosphorus, manganese, molybdenum, cobalt, boron, copper, and potassium on the basis of comparison of productive and non-productive soils. Nitrate nitrogen appeared to be in limiting quantities.

The powerfully reduced organic soils showed a potential as low as -18.2 millivolts on the hydrogen scale with almost complete hydrogen saturation and a pH of 2.9 to 3.5; drainage was exceedingly slow. Nitrification was essentially absent during the wet spring season. Lowering of the water-table by evaporation and transpiration was associated with the appearance of some nitrate nitrogen during summer.

A very high carbon-nitrogen ratio and almost continuous waterlogging have accompanied centuries of organic matter accumulation up to ten feet and over. Under these conditions applied nitrate probably is quickly reduced in the process of cellulose decomposition; and the lack of aeration confines plant roots to a thin surface horizon.

Planted slash and loblolly pines grew rapidly in drained peat on an experimental planting adjacent to a drainage canal. These were not fertilized and only two years growth were recorded.

These organic soils represent a basic primordal process of soil building from terrain slowly rising from ocean level. In the absence of good drainage fertilizers so far seem to be of little value.

BARD, G. E. 34

1946 The mineral nutrient content of the foliage of forest trees on three soil types of varying limestone content. Proc. Soil Sci. Soc. Amer. 10: 419-422.

BARNES, R. L. AND C.W. RALSTON 35

1953 The effect of colloidal phosphate on height growth of slash pine plantations. Res. Notes Univ. Fla. For. Sch. 1, 2 pp. aA

Height growth of two slash pine plantations in Florida was measured seven years after fertilization with colloidal phosphate. Stands on plots with heavy phosphate application (1 or 2 tons per acre) averaged 13 to 15 feet in height as compared with average heights of above 10 feet on the control plots. Applications of small amounts of phosphate in the planting holes did not stimulate growth.

BARTH, H. 36

1954 Praxis inom skogsgödsling i Tyskland (Forest fertilization practice in Germany). Växt-närings-Nytt 10: 40-47. (Swedish)

BEADLE, N. C. W. 37

1954 Soil phosphate and the delimitation of plant communities in eastern Australia. Ecology 35: 370-375.

The role of soil phosphate in delimiting communities is discussed; the higher the phosphate content of the soil, the more mesic and

taller is the vegetation. This conclusion is supported by quantitative data on the relative fertility of the soils, by transplant experiments, and by chemical analyses of the ash of leaves.

BEARD, J. S. 38

1952 The use of fertilizers in wattle cultivation. J. S. Afr. For. Ass. 22: 9-33. fa

Describes an experiment laid out in 1936 to test the efficacy of various fertilizers applied to young wattle plantations. Superphosphate was the most successful, the greatest benefit being derived when it was dug in within the first six months of the trees' life.

BEARD, J. S. 39

1953 Fertilizer experiments on black wattle. S. Afr. J. Sci. 49: 205-206. fa

Dressings of 19.1% superphosphate or of a mixture of super and raw phosphate applied in July to plantations reestablished by strip burning the previous April, produced by the following April growth results superior to those of control plots. No difference between the two treatments themselves was noticeable. Applications were made at the rate of 200 lbs./acre. A treatment with the mixture at 333 lbs./acre was also given but produced no better results than the lighter dressing.

BECKER-DILLINGEN, J. 40

1937 Die Gelbspitzigkeit der Kiefer, eine Magnesiamangelerscheinung (The yellow-tip disease of pine, a magnesia deficiency). Ernähr. Pfl. 33: 1-7.

BECKER-DILLINGEN, J. 41

1939 Die Ernährung des Waldes (The nutrition of forests). pp. 209-301. Verlagsgesellschaft für Ackerbau, Berlin.

BECKER-DILLINGEN, J. 42

1940 a Die Magnesiafrage im Waldbau (The magnesia problem in silviculture). Forstarchiv. 16: 88-92. fa

Fertilizing with MgO greatly reduced the number of yellow needles in pine and spruce seedlings on Mg-deficient soil. The effectiveness of phosphate fertilizers also depends upon the pres-

ence of MgO in the soil. Potash-magnesia (a mixture of K_2SO_4 and $MgSO_4$) is the best Mg fertilizer. Dolomite limestone may also be used. Sandy soils may be improved by pulverized basalt, gabbro, or diabase; these contain considerable MgO but are slow acting.

BECKER-DILLINGEN, J. 43

1940 b The potash requirements and fertilizing of forest trees. Ernähr. Pfl. 36: 37-43.

BEILMANN, A. P. 44

1934 a Experiments on the fertilization of shade trees. Proc. nat. Shade Tree Conf. 10: 114-126. BaA

For 7 years large and small trees of 30 spp. were supplied, by the punch bar method, various amounts of N, P, and K, singly and in combination. Growth responses of branch and trunk indicated need and general shortage of N. Best response followed application of 10-8-6 formula, basing dosage upon individual tree size. A method of pressure feeding was developed for use with power sprayer.

BEILMANN, A. P. 45

1934 b How to feed shade trees. Bull. Mo. bot. Grd. 22: 113-125.

BEILMANN, A. P. 46

1936 Feeding the shade tree. Bull. Mo. bot. Grd. 24: 95-113.

BEILMANN, A. P. 47

1946 Shade tree fertilization. Amer. Nurserym. 84: 7-8, 47-49.

BELTRAM, V. 48

1950 (Liming of nurseries). Šumarcki List 74: 187-200. (Croat. w/French summary) fa

Stresses the need of liming acid soils, and discusses in some detail the use of (1) natural limestone, (2) wood ash, (3) $CaCN_2$, (4) sugarmill carbonated lime sludge. Quotes an instance of a forest nursery on a very acid soil of the Karst red-soil type: its very poor yield was spectacularly improved by manuring it in spring with 2000 kg. olive-stone ash and 3000 kg. lime kiln dust per ha. The improvement due to this single treatment has lasted for years. An-

other instance refers to manuring a part of an acid-soil garden with muddy sediment containing road-dust. The tomato yield on the plot thus treated was 30 times greater than on the control. The paper contains a table showing the requirements for calcareous material of (1) slightly lime-deficient, (2) heavy and (3) light, very lime-deficient soils. The figures vary from 0.3 to 10 kg./sq.m. Wood ash is recommended at a rate of 0.25 to 0.50 kg./sq.m. The sugarmill carbonated sludge seems to be an ideal manure for acid soils. It has been used in many parts of Yugoslavia, increasing yields on the average by 30-50%. The sludge contains *ca.* 40% finely comminuted $CaCO_3$, a considerable amount of P_2O_5 (*ca.* 0.65%), some K, and a lot of organic matter. The proportion to be used is 10 tons/ha. for slightly acid, and 20 tons/ha. for very acid soils. The effect lasts for as long as 10 years. The paper also contains a chapter on the use of charcoal dust, which appears to promote the activity of nitrifying bacteria and checks fungal growth.

BENSEND, D. W. 49

1943 Effect of nitrogen on growth and drought resistance of jack pine seedlings. Tech. Bull. Minn. agric. Exp. Sta. 163: 1-63. L

The experiments were devised to study the effect of N on the growth and drought resistance of jack pine seedlings and transplants. The results of the investigation may be summarized as follows:

1. The height and weight of the seedling stems increased with increase in the N supply up to 200-250 ppm., and beyond this there was a decrease in both weight and height.

2. The weight of the roots increased up to 100 ppm. and further increase in N supply resulted in little change.

3. The root/shoot ratio decreased with increase in available N up to 100 ppm., after which there was little or no change.

4. The percent N in the stems and roots increased with increase in the N supply and the optimum N supply (average for roots and stems) in the seedlings was about 2.20% for sand cultures and nursery soil.

5. Seedlings grown under 200-250 ppm. N were as drouth resistant as seedlings grown under a N deficiency, but increasing the N supply above the optimum resulted in decreased drouth resistance.

6. The results of the experiments indicate that jack pine stock that has been grown in a soil with a favorable N supply will have a nitrogen content of 2.25%±0.20%; this applies to both one and two year old stock.

BENZIAN, B. 50

1951 A century old forest nursery in Germany. Forestry 24: 36-38. faA

Describes a visit to the 200-acre forest nursery of Pein and Pein in the district of Halstenbek near Hamburg. Here, on very light, sandy soil, almost continous tree crops have been grown for about 100 years. All crops except pines receive a dressing of farmyard manure as well as N, P, and K fertilizers. Lime is applied only once every 7-10 years and the land is then cropped with hardwoods for 2-3 years. Sowing is normally done in April and May, and lining out from July to October of the following year. Single boards with an attached notched metal strip are used for lining out.

BENZIAN, B. 51

1955 Nutrition problems in forest nurseries. Summary report for 1953. Rep. For. Res., Lond. 1954: 38-50.

BENZIAN, B. 52

1956 Nutritional problems in forest nurseries. Rep. For. Res., Lond. 1955: 71-72.

BERG, E. 53

1949 Gödsling ave myr (Fertilization of bog). Tidsskr. Skogbruk 57: 7-9. (Norwegian) fa

No regeneration took place within 10 years on an acre of peat bog drained in 1933. In 1943, and again in 1944 the area was treated with 50 kg. complete fertilizer per decare. Within five years, pine and birch plants 1.5-2.5 m. tall were abundant and there were some spruce plants. On a similar area treated in 1946 and again in 1948 with 20 kg./decare, regeneration was also satisfactory. Treatment with Ca $(NO_3)_2$ alone, had no effect.

BERG, E. 54

1954 Gödsling av skog (Forest Fertilization). Växt-närings-Nytt 10: 60-66. (Swedish)

BINDER, G. 55

1953 Effects of some foliar sprays on the correction of iron chlorosis in ornamental plants. M. S. Thesis, Cornell Univ., Ithaca, N. Y.

BJÖRKMAN, E. 56

1953 a Om "granens gulspetssjuka" i plantskolor (The "yellow tip disease" of spruce (*Picea abies* Karst.) plants in forest nurseries). SkogsvFören. Tidskr. 51: 211-229. (Swedish w/English summary) L

Yellow discoloration at the top of spruce plants, in southern and central Sweden in nurseries having high pH values, is probably attributable to an unfavorable potassium/calcium ratio. The high calcium content impairs the uptake of potassium. Reducing the pH with acid fertilizers such as ammonium sulfate or sulfur arrests mild forms of "yellow tip disease," but in severe cases application of potassium sulfate is necessary, which not only lowers the pH level but also raises the potassium/calcium balance. Nurseries located on soils exhausted by previous agricultural practices should have a liberal application of phosphorus, about 4 cwt. of superphosphate per acre. The present experiments have provided no grounds to assume that "yellow tip disease" of spruce is due to any deficiency of minor elements.

BJÖRKMAN, E. 57

1953 b Om orsakerna till granens tillväxtsvårigheter efter plantering i nordsvensk skogsmark (Factors arresting growth of spruce after planting on forest land in N. Sweden). Norrlands SkogsvFörb. Tidskr. 1953: 285-316. (Swedish w/English summary) fa

A series of experiments was begun in 1947 in six nurseries, in which plants were given organic and artificial fertilizers and planted out on different forest sites as 2-0 or 3-0 plants. Detailed results will be published later, but conclusions so far are that plants put out on sites poor in nutrients give better growth if they have received a moderate dose of fertilizer in the nursery, that excessive treatment with fertilizers in the nursery is associated with higher mortality after transplanting, that 2-0 grow more strongly than 3-0 plants, but that mortality is higher among the former, probably because they are rather small to handle without damage during planting,

and that mortality for both 2-0 and 3-0 plants from the poorer nursery sites is higher than for those from better sites.

In a series of greenhouse experiments 2-0, 3-0, 1-1 and 2-1 plants were planted in mineral soil from an old spruce forest and (1) left untreated, (2) given a fertilizer containing N, P, K, and Ca or (3) given enough water to maintain the water level at the height of the soil surface. (1) gave the best and (3) gave the worst root development. An examination of the roots showed better development, especially with regard to short roots, in transplanted than in untransplanted plants and with the latter in 2-0 than in 3-0 plants.

In a further greenhouse series, plants with roots damaged in six different ways and undamaged controls were given a fertilizer or left untreated, and watered at the rate of one liter/week or 20 liters/week (the actual amounts being varied slightly with the season, but the ratio of 1:20 maintained). All the plants were included in a general examination and mortality count but only four or five from each group (84 plants) were lifted for root examination. Even plants with the root system severely curtailed developed normally, mortality being lowest among plants treated with fertilizer. The water supply was especially important among plants that had not been given a fertilizer, e.g. the mortality of plants with ¾ of the root system cut away was 92% in the one liter and 25% in the 20 liter series without fertilizer. An examination of the roots showed that the most important factor was the number of points at which new roots could develop in the upper part of the root system.

It is concluded that the development of a good root system with mycorrhizae is very important and that sample plants should be examined before planting out, especially on to poor soils. Fertilizer treatment in the nursery should not be heavy enough to prevent mycorrhizal development. Transplants should be used whenever possible.

Björkman, E. 58

1954 a Om gödsling, av skogsmark (Fertilization of forest areas). Växt-närings-Nytt 10: 1-7. (Swedish) a

A short summary is given of experience with forest fertilizing in Denmark, Germany and England. In Sweden fertilizers have not been much used, but some good results have been obtained with wood ash on peat soils. There have been no responses to trace elements, Chlorate has been used as a weed killer with good effect. In

nursery practice it has been found that over-fertilized plants are apt to suffer when transplanted to the forest. The aim of nursery fertilizing should be to get a well-balanced shoot-root ratio.

Björkman, E. 59

1954 b Betydelsen av gödsling i skogsträds-plantskolor för plantornas första utveckling i skogsmarken (The importance of fertilization in forest nurseries for the early development of plants after planting). Norrlands SkogsvFörb. Tidskr. 1954: 35-58. (Swedish)

Blokhuis, J. L. W. 60

1950 De invloed van kalk bij de aanleg van bos op heidegrond (The influence of lime in the afforestation of heathland). Ned. Boschb-Tijdschr. 22: 70-72. (Dutch) fa

Series of experimental plots were laid out in 1936, treated with different quantities of lime, and planted with Japanese larch and oak. Measurements of height growth and pH in 1948 were tabulated. The height growth of both species is generally significantly increased over that on control plots. The pH of the plots is, however, lower than in1935. In another series using similar quantities of lime, a crop of lupin was grown on the plots in 1936, before planting in 1937 with oak. Sitka spruce, Norway spruce, and Douglas fir. Measurements made in 1949 showed in all cases greater height growth for trees on treated than on untreated plots.

Boomsma, C. D. 61

1949 Phosphate for top dressing as a normal plantation operation. Aust. For. 13: 108-112. fa

The standard agricultural practice of fertilizing the soil with super-phosphate has been extended to a number of young *Pinus radiata* plantations in S. Australia. Data on costs, methods of application and growth response, derived from 450 acres in Second Valley Forest Reserve, are presented and discussed. The plantations selected for treatment all showed symptoms of nutrient deficiency. Significant increases in height growth, and a change from a sparse, chlorotic crown to a normal dense habit, followed applications of superphosphate at a rate of 8 cwt./acre to plantations from 1 to 14 years old and in natural regeneration up to 15 years old. Application was by hand and the best apparatus was found to be a canvas

bag holding 50-60 lbs., carried on the back, with a tapered pipe having an outlet of 1.5 in. diameter. For trees 1-3 years old, fertilizer is concentrated around the trees in a circle of *ca.* 12-18 in. from its base. Larger trees receive a dressing broadcast evenly throughout the plantation. Costs are calculated on a basic rate of L5. 10s. 6d. per week of 40 hours and fertilizer at 8s. 6d./cwt. The labor cost/cwt./acre varied from 9d. for an 8-cwt. treatment to 7s. 3d. for a 2-cwt. treatment. Labor costs also varied with the height and density of the undergrowth. At 3% interest, the total compounded cost at rotation age (40 years) of rehabilitating defective stands with a single treatment of 8 cwt./acre at a cost of L4/acre applied at 10 years, is L9. 14s. and a 2nd treatment at 15 years amounts to L8. 8s.—a total of L18. 2s. for two treatments. Even a third treatment, if necessary, might prove economic.

Bornebusch, C. H. 62

1941 Gødskning af Planteskoler (Manuring of forest nurseries). Dansk Skovforen. Tidsskr. 29: 49-55. (Danish)

Brantseg, A. 63

1946 Granas veksthemning (Retardation of growth of spruce). Repr. Skogen og Klimaet 1946: 63-78. (Norwegian) fa

The cause of growth check and previous research thereon are discussed and various attempts to combat checking are described. Experiments were begun at the Vestland Forest Experiment Station in 1943 on destroying heather by burning and by treatment with $NaClO_3$ and $CaCN_2$. Trees planted on the burnt land were in reasonably good condition after 2-3 years. Burning is not feasible on sites liable to wind erosin, and heather reappears in a few years in the moist climate of West Norway. It is too early to estimate the effect of the chemicals, but heather appears to tolerate large quantities of either where rainfall is high. Flat-root planting, where the roots are spread and remain in the upper humus layer (where temperatures are higher) is found more satisfactory than deep-root planting. Experiments were made on the addition of 20 g. of $Ca(NO_3)_2$, superphosphate or K fertilizer, or 50 g. of lime, to the planting earth of trees planted by both methods; it is too early for definite results, but trees planted by the flat-root method, with the addition of lime and superphosphate, show particularly good height growth. Experiments begun privately in 1941 on the use of a fertilizer containing O.16%N, 15.2% P_2O_5, and 34.7% K, and of

$CaNH_4(NO_3)_3$ suggested by 1945 that the growth check had been avoided in treated trees. Trees planted by a landowner in 1939 with Tunis salt mixed in the planting soil appeared in 1944 to have escaped the growth check, but lack of controls prevented conclusive results; it is suggested that Tunis salt may free plant nutrients from the soil by ion exchange. Experiments were begun at the Research Station in 1944 on planting 2-0 spruce in pots with soil from different areas where growth check prevails, with and without the addition of fertilizers and trace elements, in the form of water-soluble salts, and with nursery soil. Height growth in 1946 is shown in a graph; best results were obtained from the addition of Ca and of P.

Boynton, D. 64

1954 Nutrition by foliar application. Annu. Rev. Pl. Physiol. 5: 31-55.

Braucher, O. L. and R. W. Southwick 65

1941 Correction of manganese deficiency symptoms of walnut trees. Proc. Amer. Soc. hort. Sci. 39: 133-136. fa

Manganese deficiency in trees of *Juglans regia* manifested by mottling and, in severe cases, burning and premature shedding of the leaves, has been corrected on an experimental scale by applying manganese salts as injections or sprays. Dry salt injections into holes bored into the wood produced a marked response in the following season if made during the summer or winter months, and early summer injections sometimes gave responses in the same season. Good results were obtained in limbs four to six inches in diameter, by injecting manganese sulphate into four holes at the rate of 5 gr. per hole. Holes should be staggered and not more than 4 inches apart. Injection of dry salts was not usually followed by severe bark injury, though some wood injury occurred. The best response to sprays of manganese sulphate resulted from applications in late May and June. Concentrations exceeding 20 lb. per 100 gallons caused leaf burn. Liquid injections and soil treatments are also under trial.

Brener, W. H. and S. A. Wilde 66

1941 The effect of non-legume green manure upon the fertility of forest nursery soils. J. For. 39: 478-482. Ba

The effect of non-legume green manure upon the organic matter content of soil and the retention of commercial fertilizers by a

" catch crop" was studied in the greenhouse and on nursery sample plots. No appreciable improvement in the fertility of nursery soils was obtained by rotations with non-legumes except when a complete fertilizer was applied prior to seeding the green manure crop. Green manuring by means of a "catch crop" converts the commercial fertilizers into plant tissue, thereby reducing the loss of nutrients by leaching and eliminating danger of chemical injury to seedling roots by soluble salts.

Brener, W. H. and S. A. Wilde 67

1948 Degeneration and recovery of composted fertilizers. Tech. Notes Wis. Conserv. Dep. 31. 5 pp. L

Prolonged storage of composted fertilizers brought about strongly pronounced deficiency of available N. This in turn annihalated the beneficial effects of composts. An application of $NaNO_3$ at the rate equivalent to 250 lbs. per acre, supplementing the application of composts, increased the average growth of black locust seedlings about four times, as compared with seedlings raised on unfertilized sandy soil. Nitrate treatment increased top-root ratio from 0.26 to 0.37, which could be considered an improvement in the general balance of planting stock.

The results of this study strongly emphasize the need for careful observations of available nitrogen in composts prepared from decay-resistant organic remains having a wide C/N ratio.

Addition of lime, horse manure, or artificial aeration produced no conspicuously beneficial effects on the quality of composted fertilizers. Abundant watering of composts during their preparation and early stages of storage is needed.

Brenneman, D. L. 68

1953 Fertilization of young loblolly pine plantations. M. F. thesis, N. C. St. Coll., Raleigh, 73 pp.

Bruning, D. 69

1952 Beobachtungen über Kali-und Magnesiummangel bei Robinie (*Robinia pseudoacacia*) und der perennierenden Lupine (*Lupinus polyphyllus*) (Observations on potassium and magnesium deficiency in black locust and perennial lupine). Ernähr. Pfl. 2: 71-82. A

In order to examine the problem regarding the effect and performance of potassium and magnesium fertilization of black locust,

red oak and pine, a fertilization experiment was carried out in the forest district Scheeren in the forest region Altmark in the spring of 1950. Parcels of land 1/5 ha. in area were treated with magnesium sulphate with and without free potassium fertilizers. The treatments were replicated 4 times. Where possible potassium-free and unfertilized plots were also established. The treatment area was influenced by ground water and was classified as a degraded average sandy site.

An 80-year-old pure pine stand (yield class 4, little wood volume, basal area 0.7) with severely spiral grained wood and coarse branching habit, was cut down immediately before the experiment was established. The natural forest type supported by this site was thought to be a transition form between the pedunculate oak/birch type and the mixed pine type. As a result of farming, followed by pure pine culture with heavy litter removal, an acidophilous moss-pine forest had developed before the experiment was initiated.

The experimental area is situated on glacial valley sand (Warthe stage) and represents a fluvio-glacial deposit. A chemical analysis of the soil before treatment showed a lack of all plant nutrients. The soil was fertilized with 2000 kg./ha. quick lime, and 40 kg:/ha. pure P_2O_5 in the form of superphosphate. No mineral nitrogen was given as black locust is a legume. On the plots with oak and pine, perennial lupine was sown in the plant rows.

The local forestry viewpoint is that the most promising way to solve the nitrogen problem seems to be the biological production of nitrogen by mobilization of humus and by planting suitable nitrogen fixing plants and timber species. Potassium was applied in amounts of 160 kg. pure K_2O only as KCl.

After liming in February 1950, potassium and phosphorus were applied at the end of March and about 4 weeks later reforestation with one-year-old seedlings was carried out. The black locust in particular reacted visibly by the end of the summer. The variations shown on photographs were supported by determination of the terminal heights in the fall of 1950. The significant difference as a result of the various potassium fertilizers amounts to 25 to 40% and for magnesium up to 10.7%.

The reported results are well in agreement with the findings of the soil analyses after Professor Dr. Arland-Leipzig's "wilting method". (Anwelkmethode) Lupine also showed a clear response to fertilization. The improvement resulting from the addition of potassium and magnesium was reflected not only in the number of

lupine plants, but also in the height growth, growth vigor, and flowering—thus in the entire habit. The experiment showed that in the amelioration of degraded sandy sites, poor in nutrients, potassium and magnesium fertilization must not be neglected.

BRYAN, M. B. 70

1954 Some effects of winter application of inorganic fertilizers to pine seedlings in the nursery. M. S. thesis, N. C. St. Coll., Raleigh.

BURGER, H. 71

1952 Bodenverbesserungsversuche, III Mitteilung (Experiments on soil improvement, III). Mitt. schweiz. Zent. Anst, forstl. Versuchsw. 28: 11-87.

BÜSGEN, M. AND E. MÜNCH 72

1931 Bau und Leben dev Waldbäume, 3. Aufl., Verlag Gustav Fischer, Jena, 1931. The structure and life of forest trees, 3rd Ed., Trans. by T. Thompson, viii+436. John Wiley, New York.

CADY, J. G. 73

1938 The role of green manure crops in the maintenance of forest nursery soils fertility. M. S. Thesis, Univ. Wisconsin Library, Madison.

CAUGHEY, M. G. 74

1947 Effects of fertilizer on growth rates of *Ilex lucida*. J. Elisha Mitchell sci. Soc. 63: 99-100. fa

Presents results of experiments to find the effect of nitrate and Ca fertilizers on *I. lucida* growing in peat soil in N. Carolina. Na NO_3 at a rate of 400 lbs. per acre produced the best growth. Shrubs treated with Ca SO_4 were markedly stunted.

CHADWICK, L. C. 75

1935 The fertilization of shade trees in the nursery. Proc. Amer. Soc. hort. Sci. 32: 357-360. Ba

In November 1931 a block of 500 Moline elms *Ulmus americana* Moline) was planted in rows of 8-10 ft. in a well prepared field of silt loam soil. The block was divided into 4 sections which received

applications of fertilizer in (1) spring, (2) spring and July, (3) July and fall, and (4) Fall. Each section was divided into 5 plots of 25 trees each. Besides the control plots the fertilizers applied to each section were an inorganic 12-6-4, and organic 6-6-4, $(NH_4)_2SO_4$ and a mixture of $(NH_4)_2SO_4$ and superphosphate. Applications were so made that each plot received about the same quantity of N at each application. In 1934 applications were computed on the basis of adding ¼ lb. of N and ½ lb. of superphosphate per inch in diameter of the tree. Fall applications of a complete fertilizer high in N or $(NH_4)_2SO_4$ plus superphosphate were the most beneficial.

CHADWICK, L. C. 76

1936 a Ohio shade-tree fertilization experiments. Proc. nat. shade tree conf. 1936: 55-65.

CHADWICK, L. C. 77

1936 b Chlorosis of pin-oaks. Proc. Amer. Soc. hort. Sci. 33: 669-673. Ba

Chlorosis of pin oaks is caused in may cases by iron deficiency. $FeSO_4$ has been applied to chlorotic trees by spraying, injection, and applying it to the soil beneath the trees. $FeSO_4$ plus S applied in holes in the soil beneath the spread of the branches gave the best control. Applications were made at the rate of ½ lb. of each to each inch diameter of the tree trunk. Soils poor in fertility should be treated with a complete commercial fertilizer. Early application and ample moisture are essential for satisfactory results.

CHADWICK, L. C. 78

1937 a Modern methods of shade tree fertilization. Proc. nat. Shade Tree Conf. 13: 63-76.

CHADWICK, L. C. 79

1937 b Fertilizer trials with shade trees in the nursery. Proc. Amer. Soc. hort. Sci. 34: 664-668. BaA

The nutrient requirements of *Ulmus americana* Moline were studied. Fall applications seem superior to spring applications. A complete fertilizer high in N or a mixture of $(NH_4)_2SO_4$ and superphosphate were the best of those tested. Applications of $(NH_4)_2SO_4$ alone gave little stimulation. K_2O seems unnecessary

for this particular soil type. Ample moisture is necessary for a favorable response of small trees to fertilizer application and it seems more important for stimulating growth of young trees in good soil than additional applications of fertilizers.

CHADWICK, L. C. 80

1939 The distribution of roots of Moline elm in relationship to fertilizer application. Proc. nat. Shade Tree Conf. 15: 38-50. fa

A study of root distribution of eight year old transplants of Moline Elm (a horticultural variety of *Ulmus americana*), unfertilized or treated with various fertilizers.

CHADWICK, L. C. 81

1940 Practices of tree fertilization. Arborist's News 9: 66-71.

CHADWICK, L. C. 82

1941 Fertilization of ornamental trees, shrubs, and evergreens. Bull. Ohio agric. Exp. Sta. 620: 1-29.

CHADWICK, L. C. 83

1943 a Diagnosis of nutritional requirements of ornamental plants. Proc. nat. Shade Tree Conf. 19: 5-19. fa

A brief account of nutritional requirements of trees and shrubs, together with notes on, and a key to, the symptoms associated with various nutrient deficiences.

CHADWICK, L. C. 84

1943 b Nitrogen, phosphorus, and potassium content of a silt loam soil following 10 years of surface application of commercial fertilizer. Proc. Amer. Soc. hort. Sci. 42: 641-645.

CHADWICK, L. C. 85

1945 Why fertilizers act as they do. Arborist's News 10: 25-29, 35-40.

CHADWICK, L. C. 86

1946 a Fertilizing shade trees. Amer. Nurserym. 83: 13. fa

Report of a conference at Ohio State Univ. on fertilizing shade trees. Various methods of injecting the fertilizer into the soil were

described, including the Irish Aero-Fertil gun through which compressed air is discharged directly into the soil, fracturing it to the required depth, displacing the soil atmosphere with air containing a supply of oxygen and correcting nutrient deficiencies by blowing fertilizer through the loosened soil. An experiment is being conducted at Ohio Agricultural Experiment Station on methods of applying fertilizers to increase the growth of trees.

CHADWICK, L. C. 87

1946 b Some facts about shade tree fertilization. Arborist's News 11: 73-77.

CHADWICK, L. C. 88

1950 Organic vs. inorganic fertilizers in tree feeding. Arborist's News: 15: 68-72. Ba

The basic elements available to plants from organic and inorganic fertilizers are the same, although they may vary in amount and availability. The cost per pound of N in organic carriers may be several times greater than in inorganic carriers. Ordinary methods employed in fertilizing trees will not add enough organic materials to change soil structure appreciably. There is no experimental work that indicates advantages of either organic or inorganic N carriers for tree fertilization.

CHADWICK, L. C., P. R. TILFORD, AND C. F. IRISH 89

1950 A study of some methods of fertilizing shade trees. Proc. Amer. Soc. hort. Sci. 55: 519-526.

CHAMPAGNE, E. G. 90

1954 Wood chip mulch improves red pine survival. Sta. Notes cent. St. For. Exp. Sta. 86. 2 pp. L

Red pine seedlings mulched with wood chips showed 20% better survival after two growing seasons than non-mulched trees, but the mulching had no significant effect on average height growth. The mulch, made from oak, hickory, elm, and aspen logging slash, was placed around the trees at the rate of 1¾ cu. ft. per tree in a 30 to 36 inch diameter circle to a depth of about 3 inches two weeks after planting. The greater survival and better vigor of the mulched trees are credited to reduced evaporation, less competition for soil moisture from adjacent vegetation, and less overtopping or shading of the trees by the tall weeds and sweet clover.

Chancerel, L. 91

1913 Action comparée du sulfate de manganese et du sulfate de calcium sur les germinations de pins maritîmes (Comparative action of manganese sulphate and calcium sulphate on the germination of maritîme pine seed). Rev. Eaux For. 52: 208-209.

Chandler, R. F., Jr. 92

1938 The influence of nitrogenous fertilizer applications upon seed production of certain deciduous trees. J. For. 36: 761-766. fa

Application of fertilizer resulted in a considerable increase of the total number of seeds produced by beech and sugar maple. Stimulation was marked in the case of sugar maple, which showed in addition an increase in the percentage of sound seed and in the dry weight of individual seeds. Although these two species only were used in the experiment, the results are considered sufficiently striking to deserve further attention. The cost of fertilizers is too high to encourage general use of the method, but tree geneticists and others wishing to obtain seed from particular trees might find it useful.

Chandler, R. F., Jr. 93

1943 The influence of nitrogenous fertilizers on the growth and seed production of deciduous forest trees. Proc. nat. Comm. Nitrog. Util. 2: 40-46.

Chandler, R. F., Jr. 94

1944 Amount and mineral nutrient content of freshly fallen needle litter of some Northwestern conifers. Proc. Soil Sci. Soc. Amer. 8: 409-411.

Chapman, A. G. 95

1933 Some effects of varying amounts of nitrogen on the growth of tulip poplar seedlings. Ohio J. Sci. 33: 164-181. L

Effects of various amounts of N on potted tulip poplar seedlings were studied. Summary of findings include an insignificant amount of nitrate N accumulated in the tissues of seedlings regardless of the concentration of ammonium nitrate added to soil medium. The total N, including nitrate N, was most abundant in the leaf and decreased in order in root, bark, and woody stem. Leaves of plants

supplied with little or no additional N had uniformly yellowish-green leaves; plants supplied with additional N equivalent to 40, 100, and 200 lbs./acre had dark-green colored leaves; but leaves of plants supplied with 400 lbs./acre additional N developed at maturity a mottled green and yellow color. Plants growing in soil having the highest and lowest concentrations of N began and broke dormancy earlier than plants of other treatments. No correlation was noted between height growth of seedlings and amount of available N during the first season after transplanting; but the greatest average height was attained during the 2nd season by plants grown in soil with N equivalents of 40 and 100 lbs./acre added per year. The greatest average weight of plants occurred with the addition of 100 lbs. N/acre. An increase in shoot-root ratio was associated with increase in N supply.

CHAPMAN, A. G. 96

1941 Tolerance of shortleaf pine seedlings for some variations in soluble calcium and H-ion concentration. Plant Physiol. 16: 313-326. fa

Germinating seed and young seedlings of *Pinus echinata* failed to survive in culture media with a soluble-Ca content of about 500 p.p.m. or more and a pH of about 6.5 or more, or with either of these factors taken separately. The possible nature of the toxic effects of high soluble-Ca and low hydrogen-ion concentrations on the root cells is briefly discussed. High Ca content of the soil may prevent natural reproduction in planted stands of this species, increase the cost of soil management in nurseries, and vitiate the results of germination tests.

CLARK, W. D. 97

1916 A cheap fertilizer for white pine seedlings. Proc. Soc. Amer. For. 11: 336.

COLLINGS, G. H. 98

1954 Commercial fertilizers. 5th Ed., xi + 617 pp. McGraw-Hill, New York.

COX, G. S. 99

1948 The influence of soil fertility on the growth of certain forest tree seedlings as affected by soil moisture and light intensity. M. F. Thesis, Duke Univ., Durham, N. C.

CROWTHER, E. M. 100

1950 a Review of work on nutritional problems in forest nurseries. Rep. Rothamst. exp. Sta. 1949: 122-129.

CROWTHER, E. M. 101

1950 b Committee on nutrition problems in forest nurseries. Summary report on 1948 experiments. Rep. For. Comm., Lond. 1948: 60-64. fa

Many transplant experiments were carried out to test the growth under uniform conditions of Sitka spruce seedlings which had received contrasted treatments in the seedbeds. The plants generally evened up, but the effects of a few treatments were still shown. Large, tender plants obtained by watering seedbeds in the drought year 1947 gave smaller transplants than those left unwatered, but additional height due to N fertilizers given to 1947 seedbeds persisted in the transplants. Transplant manuring experiments with Sitka spruce in a very acid moorland soil and on a calcareous agricultural soil, showed large responses in height to superphosphate applied before lining out to ammonium sulphate given as a top dressing in April. The only failure was on an unusually acid sandy soil (pH *ca.* 4.0) at Wareham, where a top dressing with ammonium sulphate checked height growth; other soluble N fertilizers gave good results.

CROWTHER, E. M. 102

1951 a Sub-committee on nutrition problems in forest nurseries. Summary report on 1949 experiments. Rep. For. Res., Lond. 1949-50: 97-105. fa

In seedbed experiments in which composts and bulky organic manures were compared with artificial fertilizers, markedly poorer stands of seedlings were obtained in the compost-treated beds. This was a reflection of the drought effect in a particularly dry season in soils lightened in texture by bulky organic manures, and confirms experience in similar experiments done by the Research Branch. Soil acidification experiments have provided useful information on the degree of damage to be expected when sowing follows application of acid at too short an interval. Where an adequate period elapsed between acidification and sowing, improved growth of seedlings was obtained in Kennington nursery (near Oxford) and at Ampthill nursery (Bedfordshire).

In transplanting experiments, it was confirmed that there was no apparent advantage (in respect of growth and survival of plants) in raising them in compost-treated seedbeds as compared with artificials; plants of equal size raised with artificial fertilizers in the nursery, grew just as well, both as transplants and in the forest. A positive response of Sitka spruce to phosphate was consistant in all four forests where the experiments were done. Scots pine did not behave so regularly, and was even reduced in growth by applications of phosphate at King's Forest (East Anglia). Nitrogen, as might be expected in a drought year, depressed growth of both Sitka spruce and Scots pine. Trials of fertilizers in the form of pellets, with the object of reducing the speed of diffusion and prolonging the time of action, and also reducing the risk of damage to roots during periods of unfavorable weather, did not achieve the first objective, as the soluble nutrients dissolved out of the core of gypsum much faster than had been hoped.

Crowther, E. M. 103

1951 b Nutritional problems in forest nurseries. Rep. Rothamst. Exp. Stat. 1950: 40-41.

Crowther, E. M. and B. Benzian 104

1952 Sub-committee on nutrition problems in forest nurseries. Summary report on 1950 experiments. Rep. For. Res., Lond. 1950-1951: 113-122. a

Results of several series of trials are reported. There was no consistant difference between seedlings raised with fertilizers and those raised with composts, provided adequate amounts of NPK were given. With several organic materials tested there were large improvements from additional fertilizers. The P and K fertilizers worked well, but gains from N fertilizers were more restricted. Acidification of seedbeds particularly with $(NH_4)_2SO_4$ proved beneficial, but there were indications that the optimal pH ranges of most conifers are wide or perhaps ill-determined. The beneficial effects of formalin treatment were confirmed under all manurial conditions and particularly where compost was also used. Formalin or steam may produce higher concentrations of NH_3 in seedbeds. Inorganic NPK applied as two pellets, each of 28 g., placed about 6 in. from Sitka spruce of Scots pine was, as a rule, effective, mainly because of the P supplied.

1953 Sub-committee on nutrition problems in forest nurseries. Summary report on 1951 experiments. Rep. For. Comm., Lond. 1952: 94-107. a

Top dressing one-year Sitka spruce seedlings in established nurseries on neutral or slightly acid soil with $(NH)_4{}_2SO_4$ does not always produce taller seedlings than top dressing with Nitrochalk. One year seedlings of six species of conifers at Wareham all responded to N, P and K, and there was some evidence that super applied in a previous season exerted a residual effect. Super is equal to or better than other phosphate fertilizers. In general seedling density was greater after application of fertilizers than after application of compost. It is impractical to substitute steaming for application of formalin. Treatment with formalin, steam or acid increased the NH_3 content of the soil and it is possible that the maintenance of a high NH_3 content may favour the growth of young conifers by checking nitrification. About 250 ml./sq. yd. of formalin is ample. The forest performance of Sitka spruce and Scots pine seedlings and transplants raised in the nursery on compost plus fertilizers was similar to that of plants raised with fertilizers alone. In general NP applied in the forest improved the growth of Sitka spruce and Scots pine. At Wareham forest application of super improved growth, but the effects of Nitrochalk and K were negligible. K improved the growth of Scots pine seedlings and transplants on a thin sand over chalk. A fine fibrous root system is thought to be pathological and plants with straight tap roots and thick laterals are to be preferred.

Crowther, E. M., R. G. Warren and B. Benzian 106

1954 Nutrition problems in forest nurseries. Summary report for 1952. Rep. For. Res., Lond. 1953: 84-100. a

So far there has been little benefit from using organic manures instead of inorganic fertilizers or from interrupting continuous Sitka spruce seedbeds to introduce rotation crops. In four years a healthy heathland nursery could be reduced to the state of a poor established nursery on agricultural land by using seedbed covers containing limestone. In general, growth of conifer seedlings was poorest on alkaline soils, $(NH_4)_2\ SO_4$ was better than Nitrochalk on neutral or slightly acid soils. When seedbeds are sterilized with

formalin, the formalin must be applied well before the plants have been set out in the beds. Chloropicrin was equal to or better than formalin. The residual effect of nursery treatments on growth in the forest is slight. The response to fertilizers in the forest is very variable.

CUMMINGS, W. H. 107

1941 Fertilizer trials for improved establishment of shortleaf pine, white ash, and yellow poplar plantings on adverse sites. J. For. 39: 942-946. faA

The tests involved the application of 27 mixes of fertilizer supplying ¼, ½, or ¾ gram each of N, P_2O_5, and K_2O per tree, with supplements of acid peat or dolomitic limestone. The fertilized trees showed no marked superiority over untreated trees in height increment through the first two years, although differential effects of the individual nutrients are shown for the different species. While results of these tests afford no basis for recommendations for planting practice, they suggest that the following treatments might well be used in further tests on these species: shortleaf pine—fertilizers with low nitrogen, high phosphorus, very low potassium, and supplements of acid peat; white ash—fertilizers with high nitrogen, low phosphorus, very low potassium, and supplements of acid peat; yellow poplar—fertilizers with medium nitrogen, very low phosphorus, low potassium, and dolomitic limestone filler.

CUMMINGS, W. H. 108

1944 Black locust plantation soil treatment for increased post production. Rel. Tenn. Valley Auth. Dep. Agric. 1944, 4 pp.

DALE, J., A. L. MCCOMB AND W. E. LOOMIS 109

1955 Chlorosis, mycorrhizae and the growth of pines on a high-lime soil. For. Sci. 1: 148-157. A

Jack pine was grown from seed on calcareous Ida silt loam of pH 8.2 to determine if a chlorotic condition frequently observed on pines in field plantations could be corrected by treatment with NPK fertilizers alone, in combination with each other and with certain micro-nutrients; by acidification of the soil; by soil inocu-

lation with unsterilized humus from a healthy pine plantation; and by treatment with different sources and levels of iron.

Normal growth was obtained only in soil treated with unsterilized humus. All the seedlings in humus-treated soil possessed mycorrhizae while seedlings in the other treatments were not mycorrhizal. Soil acidification produced a significant increase in growth as compared to the controls, but the seedlings were not normal and probably would not have survived the second growing season. None of the iron treatments, alone or in combination with NPK in the absence of the mycorrhizae prevented chlorosis.

The results are briefly discussed in relation to the possibility of obtaining normal pine growth on high-lime soils. A need exists for a comprehensive study of the ecology of the soil fungi which form mycorrhizae.

DAVY, C. B. 110

1953 a Sawdust composts: their preparation and effect on plant growth. Proc. Soil. Sci. Soc. Amer. 17: 59-60. A

Greenhouse studies demonstrated that application of fresh sawdust at the rate of 40 cu. yds, per acre strongly depressed the growth of deciduous and coniferous tree seedlings and green manure crops. Treatment of sawdust with anhydrous ammonia, phosphoric acid, and potassium sulfate failed to alleviate completely the adverse influence of sawdust and necessitated additional treatment of stock with nitrogen fertilizers.

In order to decrease the C/N ratio, chemically treated sawdust was inoculated with *Coprinus ephemerus*. This organism proved to be efficient in decomposition of cellulose, and within three months converted sawdust into a finely divided dark brown material which resembled a rich mull-like soil in appearance. The fermentation was invariably accompanied by a volunteer invasion of fungus gnats, *Sciaridae* spp., and many other microorganisms.

Application of composted sawdust to a sandy soil produced marked increase in growth of coniferous and deciduous seedlings and medium red clover.

DAVY, C. B. 111

1953 b Decomposition of hard maple sawdust by treatment with anhydrous ammonia and inoculation with *Coprinus ephemerus*. Trans. Wis. Acad. Sci. Arts Lett. 42: 177-182.

DAVY, C. B. 112

1954 Evaluation of composted fertilizers by microbiological methods of analysis. Trans. Wis. Acad. Sci. Arts Lett. 43: 93-96.

DAVY, C. B. 113

1955 Transformations of sawdust in the course of its decomposition under the influence of *Coprinus ephemerus*. Proc. Soil Sci. Soc. Amer. 19: 376-377. A

Sawdusts of jack pine, sugar maple, and red oak were treated with anhydrous ammonia, neutralized with H_3PO_4, enriched with K_2SO_4, and inoculated with *Coprinus ephemerus*. Compost mixtures were prepared in earthenware jars in greenhouse cultures at two week intervals to permit simultaneous analysis of composts at various stages of decomposition.

The results of chromatographic analysis indicated that *C. ephemerus* is not selective in its sugar utilization, although it consumes hemicellulose somewhat earlier than alpha-cellulose. A chromatogram of the hydrolysate of *C. ephemerus* showed almost exclusively glucose.

The course of fermentation of pine and maple sawdust was characterized by a decrease in the cold water extractables and the alcohol-benzene solubles. Oak sawdust, however, gained in alcohol-benzene solubles. Both oak and maple sawdust showed an appreciable loss of holocellulose and lignin methoxyls, but a considerable increase in lignin and base exchange capacity. Pine sawdust attained a nearly 100% increase in base exchange capacity but failed to reveal a clear picture of transformations in its structural building blocks. The consistant increase in the base exchange capacity in decomposed sawdust of all types investigated assures the values of the organism in the preparation of soil-improving organic fertilizers.

DAVIS, D. E. 114

1948 A contribution to the study of calcium deficiency in *Soja urax* and *Pinus taeda*. Ph D. Thesis. St. Univ. Ohio. Library, Columbus. Ba

Reducing the Ca content of nutrient solutions for soybeans from 200 p.p.m. to below 10 p.p.m. greatly decreased yield. Ca-deficient solutions produced markedly inferior specimens of loblolly pines as compared with plants raised in solutions where 200 ppm. of Ca was present.

1949 Some effects of calcium deficiency on the anatomy of *Pinus taeda*. Amer. J. Bot. 36: 276-282. faA

Two sets of loblolly pine (*Pinus taeda*) were cultured for one year in solutions containing respectively 200 ppm. and 2-5 ppm. Ca. The Ca-deficient pines differed for those receiving 200 ppm. Ca in the following ways: (1) terminal buds were smaller, shorter, and had dead brown scales; (2) stem tips were smaller in diameter and pointed; (3) mitotic figures were fewer; (4) cross-sections of very young leaves were smaller and both the cell number and size were less; (5) cross-sections of older leaves were also smaller, with fewer cells, smaller areas of xylem and phloem, and thicker epidermal and hypodermal cell walls; (6) stem cross-sections, 10,000/u from the tip, showed much less primary tissue, in particular cortex and pith, and much more secondary tissue, especially xylem; and (7) the root tips were more blunt and rounded, and covered with a layer of dead, partly disintegrated cells. Cell division in the Ca-deficient plants was retarded more than cell enlargement and differentiation. Thus there was fewer cells separating the meristems from lignified xylem.

DAY, G. M. AND W. R. ROBBINS 116

1950 Observations on the growth of red spruce in sand culture. J. For. 48: 689-692. fa

Picea rubens seed was sown in about 4 in. of sterile quartz sand in flat boxes kept in a greenhouse with a temperature of *ca.* 70-80°F. by day and 60°F. by night. The sand was kept moist by addition of distilled water. Seed had all germinated six weeks after sowing, and distilled water was replaced by a daily flushing with a dilute nutrient solution containing 70 ppm. of N, all as Ca $(NO_3)_2$. After two months of this treatment, the foliage appeared to be a little chlorotic, and for the next three months a solution was used containing 98 ppm. of N(⅔ as Ca $(NO_3)_2$ and ⅓ as $(NH_4)_2$ SO_4). At the end of this period the seedlings were 4-6 in. high, or some three times as high as one year seedlings grown in the field and about equal to 2-1 transplants. It is pointed out that comparisons of this kind cannot be very accurate, since in natural conditions red spruce almost invariably displays a root system completely invested with ectotrophic mycorrhizae.

The color of red spruce leaves, long used as a diagnostic feature, and variously described as yellow-green, deep green, or simply non-glaucous, is seen to depend on nutrition and to be an imperfect criterion for species identification.

DEKATOV, N. E. 117

1947 (Stimulating the growth of woody plants by chemical treatment of the soil.) Timb. Ind., Moscow 7 (6): 15-17. (Russian)

DELEVOY, G. 118

1946 Le Dilserbosch en 1941 (The Dilserbosch [plantations] in 1941). Bull. Soc. for. Belg. 53: 385-405. fa

These plantations of mixed pines and broadleaved species were established in 1902, managed partly as selection forest and partly as coppice with standards and given different amounts and mixtures of chemical fertilizers (chalk, kainite and basic phosphate). Special attention is given to the remarkable resistance of these mixed stands to unfavorable factors, not only insect and fungus attack, but also wind throw and, particularly, fire. Average annual increment varied from 4.8 to 7.7 cu. m. between the ages of 30 and 40. Natural regeneration of the broadleaved species appears to be assured and that of the conifers possible. The most satisfactory form of management seems to be an intensive selection system. The effect of the application of fertilizers at the time of planting was still apparent after 40 years, and was indeed even more marked than at 30 years. The dosage should be varied according to the species planted, e.g. the proportion of Kainite should be increased for *Quercus borealis* and that of chalk for *Pinus nigra.*

DEMORTIER, G., *et al.* 119

1950 Contribution à l'étude de l'alimentation azotée, phosphatée et potassique du peuplier (Contribution to the studies on nitrogen, phosphate and potassium nutrition of the poplar). Rapp. Cong. Int. Industr. agric. 8th. 2: 242-247. A

Pot experiments on poor sandy loam show a beneficial influence of N fertilization on the growth of poplar slips taken on shoots of one year slips.

Action of P and K fertilization is not so important.

Notwithstanding the fact that no practical doses for nursery fertilizing can be inferred from pot cultures, it may be of interest to note the best relation found between the three major elements, for the conditions of the experiment.

This relation is the following one

N	2
P_2O_5	1.5
K_2O	1

DEMORTIER, G., *et al.* 120

1954 Le développement des boutures de *Populus robusta* Schneid. en fonction du pH et du rapport Ca/Mg (The development of cuttings of *Populus robusta* Schneid. as a function of pH and Ca/Mg ratio). Bull. Inst. agron. Gembloux 22: 10-17.

DEMORTIER, G. AND J. FOUARGE 121

1936 Note sur les conditions de végétation des semis de Pin sylvestre en fonction de la reaction du sol (A note on the growing conditions of Scotch pine (*Pinus silvestris*, L.) as related to soil reaction). Bull. Inst. agron. Gembloux 5: 3-11. L

Experiments have been conducted in culture jars, in silicious soil and under ideal conditions of growth. The pH values of the soils ranged from 4 to 7. Taking into consideration the conditions of the trials, the writers consider 6.1 as a close estimation of the optimum pH for the development of Scotch pine seedlings.

DEMORTIER, G. AND J. FOUARGE 122

1938 Récherches sur l'alimentation azotée, phosphatée et potassique de semis de Pin sylvestre (*Pinus sylvestris* L.) (Studies on the nitrogen, phosphate and potassium nutrition of Scots pine seedlings). Bull. Inst. agron. Gembloux 7: 173-193. faA

Pot experiments on the fertilizing of Scots pine seedlings with ammonium sulfate, sodium nitrate, dicalcium phosphate, and potassium chloride showed that (a) the seedlings had a definite need of nitrogen and phosphate; (b) they responded far less to potash; and (c) nitrogen as ammonium sulphate was much more favorable

than as sodium nitrate. The experiments are preliminary only, and no indication can yet be given of the correct doses for nursery application.

DENUYL, D. 123

1944 Effect of fertilizer treatments on the growth of planted black locust. J. For. 42: 450-451. fa

In planting black locust (*Robinia pseudoacacia*) on a compact subsoil deficient in plant nutrients, the application of a complete fertilizer, 2-12-6, in each planting hole at the rate of one tablespoon per plant, resulted in a marked increase in height and diameter growth and root development in comparison with untreated controls. This effect of the fertilizer has continued for the four years that measurements have been made.

DENUYL, D. 124

1956 Foliage color of pines. Bull. Indiana Christ. Tree Growers' Assoc. 5: 12-15.

DETWILER, S. B. 125

1943 Better acorns from a heavily fertilized white oak tree. J. For. 41: 915-916. Ba

A lawn specimen of *Q. alba* received a spring application of 14,000 lbs./acre of fertilizer containing 10% N, 4% P and 6% K, placed in holes 18 inches apart. The fall acorn crop was 4-5 times greater than the maximum crop recorded in the previous 14 years.

DEUBER, C. G. 126

1930 Fertilization of hardwoods. Proc. nat. Shade Tree Conf. 6: 58-67.

DEUBER, C. G. 127

1937 Heavy applications of fertilizers to shade trees. Proc. nat. Shade Tree Conf. 13: 76-80.

DEUBER, C. G. 128

1939 Tests of the capacity of shade trees to utilize fertilizers. Bull. Bartlett Tree Res. Lab. 3: 3-19.

DITTIMAR, O. 129

1953 Eine mathematisch-statistische Auswertung zweier Düngungsversuchsreihen auf armen Talsanden des nordostdeutschen Diluviums (A statistical appraisal of two fertilizer trials on poor valley sands of the NE German diluvium). Arch. Forstw. 2: 552-586.

DUCHAUFOUR, P. 130

1950 Observations sur "la faim d'azote" de l'épicea (Notes on nitrogen deficiency of spruce). Rev. for. Fr. 1950 (1): 1-4. fa

It has been observed that whereas spruce (*Picea abies*) plantations can be successfully established on *Genista pilosa* or *Pteridium acquilinum* heaths, they suffer severe check or die-back on *Calluna* heath, where pine does well. Investigation of several sites showed that the A1 horizon of the *Calluna* sites had 9.6-13.4% organic matter content and C/N ratios ranging from 18.3 to 21. The corresponding figures for *G. pilosa* sites were 6.9% and 13.2 and for *P. aquilinum* sites 7.8 and 12.7. It is concluded that the failure of spruce on the *Calluna* sites is due to lack of available nitrogen in the A1 horizon where the greater part of its shallow, spreading root system is situated. The tap roots of pine, on the other hand, go down to the A2C horizon, which is rich in mineral nutrients. It is also to be noted that spruce is a very poor mycorrhiza former. To establish spruce on such sites it is necessary to mix it with N fixing species such as *Pinus pinaster*, alders, *Robinia*, or even *Genista* or gorse.

DUCHAUFOUR, P. 131

1953 Note sur l'influence de l'incinération sur l'evolution de l'humus (Note on the influence of burning on the development of humus). Ext. Act. Congr. Luxem. 1953: 729-732. A

The burning of vegetation and organic matter is a simple and practical method to improve raw humus, forming a dense felty mat, covering the mineral soil of certain podzolic areas (heathlands of Gascogne in the southwest of France).

This burning should be incomplete; a part of the organic matter is burnt and lost, the remainder on the other hand is biologically activated; a notable rise in the pH and a considerable increase of the mineralization process can be observed.

Although the effects of this burning are immediate and favorable for the seedlings, it is dangerous from the viewpoint of the future development of the forest soil. Burning encourages a decline in the reserves of nitrogen and bases. It is of importance that the soil is covered with regenerations or plantations quite soon after the burning.

DUCHAUFOUR, P. AND F. MANGENOT 132

1956 Récherches sur l'évolution expérimentale de certains humus (Studies on the experimental development of certain humus). Ann. agron., Paris. 1956: 2. A

Raw humus and peats of high acidity and poor in nitrogen were placed in plastic pans and incubated at 28-30 degrees centigrade under nearly optimum conditions of humidity and aeration. To the four fractions into which each sample was divided, the following treatments were applied: (1). mechanical treatment (sieving); (2). mixing with $(NH_4)_2SO_4$, (3). mixing with $CaCO_3$ until neutral; (4). mixing with $(NH_4)_2SO_4$ and $CaCO_3$.

Ammonium nitrogen and nitric nitrogen determinations were made twice per week. In addition, all samples were subjected to a complete bio-chemical and micro-biological analysis after one month and at the end of 4 months.

In a very acid environment the fungus microflora is not able to fix ammonium nitrate in the organic form nor to synthesize humic acids; it only offers a weak mineralizing activity of organic nitrogen. On the other hand, in an environment previously neutralized by calcium carbonate a microflora dominantly of bacteria and actinomycetes develops. Under its influence ammonium nitrate is fixed in an organic form, which gives rise to an important production of humic acids. At the same time the C/N-ratio is notably lowered.

Hence the application of calcium amendments supplemented by a mechanical treatment seems capable of transforming raw humus or inactive peats into the biologically active humus of the mull type.

DUNLOP, A. A. 133

1936 Sand culture of seedlings. Bull. Conn. agric. Exp. Sta. 380. 159 pp.

DUNN, S., *et al.* 134

1952 Field plot studies with sawdust for acid improvement. Plant and Soil 4: 164-170. fa

Field plot tests were undertaken in order to compare the effects of (1) rotted sawdust, (2) fresh sawdust, and (3) farm manure, as soil improvers. No significant difference was observed in yields of maize from plots treated with (1) and (2), though there was a slight trend in favor of (1). Heavy applications of fertilizers were necessary for the first three years. All the organic materials tended to prevent pronounced fluctuations in moisture.

EDWARDS, M. V. AND G. D. HOLMES 135

1951 Experimental work in nursery. Rep. For. Res., Lond. 1949-50: 12-24.

EGGERT, R. L. et al. 136

1946 The movement of phosphorus in red maple and apple trees in winter using radioactive phosphorus as a tracer. N.H. agric. Exp. Sta. Bull. 91.

ELSÄSSER, A. 137

1951 Technik und Wirtschaftlichkeit der Waldkalkung in Österreich (The technique and economies of liming in Austrian forests). Öst. Vjschr. Forstw. 92: 154-161. fa

Discusses the cultivation needed to mix lime with the soil, the value of lupine cultivation in conjunction with liming, and the different mechanical methods, especially the use of a forced-draught blower, of spreading the lime in mountains; gives estimated costs for Austria, and actual costs, considerably lower because of transport conditions, for Bavaria.

ENGSTROM, H. E. AND J. H. STOECKELER 138

1941 Nursery practice for trees and shrubs suitable for planting on the prairie plains. Misc. Publ. U.S. Dep. Agric. 434. 159 pp. A

Broadleaf nursery stock at Towner Nursery, Towner, North Dakota, showed marked response to fertilization with 20 tons of sheep manure fortified with 150 to 200 pounds per acre of 45-percent superphosphate.

Minimum fertility standards for growing broadleaf trees and shrubs in the prairie plains are as follows:

Total nitrogen—.15 percent
Available nitrogen—40 pounds per acre
Available phosphorus—100 pounds per acre (as P_2O_5)
Available potash—300 pounds per acre (as K_2O)
Replaceable calcium—10 m.e./100 g.
Replaceable magnesium—3 m.e./100 g.
Cation-exchange capacity—15 m.e./100 g.

FABRICIUS, L. 139

1938 Bodendeckung mit Pflanzenstoffen (Soil covering with plant materials). Forstwiss. Zbl. 60: 1-15. Ba

The effect of covering the soil was investigated on a series of plots in a mixed plantation of pine and spruce on poor soil in Franconia. On 1 pair of plots the heather and other ground cover was uprooted and removed, in 1929; on another pair the heather and other cover was uprooted and left on the plots, together with the material removed from the 1st pair; the 3rd pair received the same treatment except no material was added; and the vegetation on the 4th pair of plots was not disturbed but was covered with a heavy layer of heather and other vegetation cut in the vicinity. Heights of the pines and spruces were measured in the autumn, 1932-1936. For the last pair of plots the heights of pine in 1936 were 2.21-2.55 times those on the untreated check plots, and the heights of the spruce were 2.70-3.24 times those on the check plots. The other treatments resulted in considerable increase in height growth of the pine, but not of the spruce. Decaying heather in the soil appears to be more beneficial than decaying vegetation on the surface. In Grafrath Forest (near Munich) plots in a plantation of 50-year-old spruce were covered in 1928 with a layer of spruce twigs. The effect was not conclusive at the end of 1930, but by 1933 growth on these plots were clearly ahead of that on untreated plots, and at the end of 1937 heights on treated plots averaged 20% greater and basal area 30% greater. Other forest oak plantations were treated by covering with 50 cm. deep layers of mixed pine and spruce twigs. This resulted in greater height and basal area growth than on untreated areas. Mulching of plantations with heather and logging slash is beneficial to the young stands.

FABRICIUS, L. 140

1939 a Kalkdüngungsversuch I (Experiments on the liming of forest soils I). Forstwiss. Zbl. 61: 129-137. fa

A definite response of young spruce and pine was observed in the course of six years immediately following the treatment of soil with lime.

FABRICIUS, L. 141

1939 b Kalkdüngungsversuch II (Experiment on the liming of forest soils II). Forstwiss. Zbl. 61: 228-237. fa

In experiments undertaken at Wendelstein near Nuremberg, 1929-1937, the treatment of extremely lime deficient soils with varying applications (2,000-5000 kg./ha.) of quick lime and chalk did not produce any response in pine seedlings during the eight years following liming and sowing. On the other hand, applications of 2,000 kg./ha. of either quick lime or chalk were sufficient to obtain satisfactory growth in spruce and larch and to assure their survival in mixture with pine. In none of the plots did quick lime prove greatly superior to chalk.

FABRICIUS, L. 142

1940 Ein 10-jähriger N-Düngungsversuch (A 10-year experiment on nitrogen fertilizing). Forstwiss. Zbl. 62: 76-89. fa

Report on fertilizer trials begun in 1928 in a 33 year old stand of Scots pine on sandy soil. Plot given N fertilizer showed greater diameter, basal-area and volume increment after five years than untreated plots, but mere soil cultivation and the application of fertilizers without N resulted in less growth than in check plots. The stimulation of growth by the fertilizer was restricted to the period 2-5 years after application. No effect on height growth was observed. During the second five year period, plots treated with K and P without N showed slightly more growth than the others.

FAULKNER, R. 143

1955 Experiments on applying various forms of nitrogen to Sitka spruce seedbeds in Scotland. Rep. For. Res., Lond. 1954: 91-101.

Faulkner, R., and G. D. Holmes 144

1952 Experimental work in nurseries: composting and trials of composting. Rep. For. Res., Lond. 1950-51: 20-21. fa

On heathland soils, composts made from sawdust or heather as base materials did not improve the growth of Sitka spruce seedlings, but all straw composts considerably increased both growth and plant percent. Slaughterhouse blood applied to beds in the previous autumn, at 4500 gal./acre, increased the growth of Sitka seedlings in the following season to an extent about equal to that resulting from an application of 20 tons of bracken/blood or bracken/hops compost per acre. In composting straw, the addition of 15% by volume of succulent material such as grass mowings, along with the nitrogenous activator, greatly improved breakdown. Satisfactory straw composts can be prepared by using $(NH_4)_2 SO_4$ or nitrochalk, provided that a moisture retainer is added and acid conditions prevented.

Faulkner, R., and G. D. Holmes 145

1954 Experimental work in nurseries. Rep. For. Res., Lond. 1953: 17-31. a

Steam is better than formalin as a soil sterilizing agent, but its use commercially is impracticable. Formalin sterilization was not always satisfactory. Chloropicrin may prove useful for sterilizing soil. Placement of P and K below band-sown seed produced taller seedlings than did broadcast seed over broadcast fertilizers, but the seedling yield per lb. of seed was lower from placed fertilizers and band sowing than from broadcast methods. P was most effective when applied 2-16 weeks before sowing. Artificial fertilizers produced better seedlings than did compost fertilizers or compost alone. Krilium had little effect on seedling growth on heavy soil.

Faulkner, R. and A. MacDonald 146

1954 Inchnacardoch nursery long term soil fertility trial. Branch Pap. For. Res., Lond. 15: 15 pp. a

Artificial fertilizers improved the height and quality of the trees, but not as markedly as when a green crop was introduced into the rotation. A green crop alone had no effect. Green crop plus farmyard manure plus fertilizer produced the best trees.

FINN, R. F. 147

1942 Notes on the resampling of certain fertilized plots. Black Rock For. Pap. 1: 103-105. fa

The following results were observed 4-5 years after fertilizing:— (1) plots fertilized with sodium nitrate-ammonium sulphate showed a significant decrease in available nitrogen; (2) plots fertilized with dried blood showed a significant increase in available nitrogen; (3) rock phosphate plots showed a significant decrease in available phosphorus; (4) potassium availability increased on plots fertilized with potassium chloride; (5) nitrogen availability can be increased by proper thinnings.

FINN, R. F. AND H. H. TRYON 148

1942 The comparative influence of leaf mould and inorganic fertilizers on the growth of red oak. Black Rock For. Pap. 1: 107-109. fa

Leaf mold, sodium nitrate and superphosphate were each applied to plots on an area bearing mixed oak overwood. The previous stand had been clear cut in 1895 and the area had been cut over and severely burned several times previously. Greatest increase in radial growth of the oak was obtained with the organic fertilizer.

FLETCHER, P. W. AND J. OCHRYMOWYCH 149

1955 Mineral nutrition and growth of eastern red cedar in Missouri. Res. Bull. Mo. agric. Exp. Sta. 577. 15 pp. A

The objectives of this study were (1) to determine how much the mineral composition of eastern red cedar foliage and twigs varied with soil, season, age, and sex of the tree and (2) to determine the influence of the principal nutrient elements on seedling growth of this species. From both field and nursery investigations the major conclusions were (1) rich, calcareous soils produced maximum seedling growth (length and bulk) but least ash per unit of oven-dry matter, (2) soluble phosphorus and exchangeable calcium in the silt-loam soils were directly related to seedling growth, (3) the concentration of phosphorus in the foilage of seedlings and mature trees was related directly to its concentration in the silt-loam soils studied, (4) the foliage, compared to the twigs, contained greater concentrations of potassium, magnesium, and phosphorus, about the same proportion of silica and total ash, and a lower con-

centration of calcium, and (5) the calcium content of foliage from female trees increased as the growing season advanced, but that of male foliage remained relatively constant.

FOLL, S. C. 150

1949 Soils and fertilizer relationships to tree development. Proc. nat. Shade Tree Conf. 24: 5.

FREYTAG, M. A. 151

1951 Effect of fertilization on the quality of seed produced in a potash deficient plantation of Norway and white spruce. Unpub. Rep. State Univ. of N.Y. Coll. For. Syracuse.

GAMBI, G. 152

1955 Essais comparatifs d'engrais, en surface et en profondeur, en populiculture specialisée (Comparative trials of fertilizers, applied on the surface or in holes, in specialized poplar growing). Int. Poplar Comm. (Madrid) 6 pp.

Experiments in the application of a complete NPK fertilizer, to 1-year-old plantations of 3 different clones of *Populus canadensis*, (1) scattered on the surface, in a radius of 50 cm. from each tree, and (2) put in holes at a depth of 20-30 cm., and 40 cm. distant from the tree at a rate in each case of 2 kg. per tree, showed no significant difference between the 2 methods. Fertilizer treatment produced striking increases in diameter and height growth over controls.

GALLOWAY, H. M. 153

1938 A comparison of rock phosphate and superphosphate as sources of phosphorus for the growth of coniferous seedlings. Tech. Note Wis. Conserv. Dep. 20: 1 p. L

The use of commercial fertilizers having a comparatively high degree of solubility may result in a concentration of soil solution toxic to seedlings, especially in the case of poorly buffered sandy soils. Rock phosphate and superphosphate as sources of phosphorus were compared for the growth of Norway spruce in sand cultures. Rock phosphate produced long, deep pentrating root systems, whereas superphosphate produced a shorter root system, consisting

largely of horizontally oriented laterals. The beneficial effect of rock phosphate should be attributed to the slower solubility of salt and its tendency to remain in situ instead of accumulating in toxic concentration near the surface.

GALOUX, A. 154

1954 La fertilization minérale en sylviculture (Mineral fertilization in silviculture). Trav. Sta. Rech. Groenendael, Série B: 16: 62 pp. A

Belgium is one of the first western European countries where mineral fertilization has been made the object of systematic experiments, which have been continued to the present day. This research was initiated in about 1900 and we are able from now on to draw important conclusions regarding the fertilization of bare areas before afforestation. Experiments have established the following facts:

(a) It has been very well proven that certain phosphorus, potassium, and lime fertilizers, when applied a little at the time, before or after the establishment of forest stands on poor soils, can speed up the growth of the stands.

(b) The effect of phosphorus fertilizers, containing P_2O_5 in soluble form is more evident than that of others.

(c) Of the quantities (100, 150, 200, 265 kg.) of P_2O_5 applied per ha, it is difficult to determine the optimum amount. These applications have given noticeably uniform results.

(d) The quantities of lime and kainite which have had a noticeable result on the growth of the stands are 2000 and 5000 kg. of slaked lime and about 500 kg. of kainite per ha.

(e) On light sandy soils the surface application of fertilizers can give good results.

(f) It has been shown that on heavy soils the best technique is to apply the fertilizers in the planting holes, mixing them with the fill.

(g) The lead in growth, observed after the fertilization of young stands is a performance peculiar to youth. This lead does not increase during the development of the stands but maintains itself for a very long time. It is, in general, always perceptible to about 40 to 50 years and is reflected in the total production of woody material.

(h) The fertilization gives the plantations a lead which can be evaluated in years of growth. It is in general 2 to 3 (4) years and maintains itself during the life of the stand. The total production of the fertilized stand can thus be considered as that of one non-

fertilized plus 2 to 3 (4) years of growth. The excess of total production at a given age is thus equal to 2 to 3 (4) times the current annual increment, corresponding to the age under consideration. This means that the excess of production varies considerably with the woody species.

(i) It has also been demonstrated that the application of fertilizers favored the recovery of plants in the plantation.

(j) It is evident that in intensive silviculture, fertilization cannot result in important production gains, but in general the excess of production compensates for the cost of the fertilization.

Table: Development of the mean total height of fertilized and non-fertilized Scotch pine stands.

AGE (YEARS)	4	7	10	25	30
Fertilized stands, tot. ht. in cm.	66	136	229	883	1074
Non-fertilized stands, tot. ht. in cm.	43	101	174	809	1004
Difference	23	35	45	74	70
% difference	+53	+34	+25	+9	+6

GALOUX, A. 155

1955 La fertilization minérale en sylviculture (Mineral fertilization in silviculture). Bull. Soc. for. belg. 62: 360-381.

An abbreviated version of GALOUX, A., 1954.

GEMMER, E. W. 156

1932 Well-fed pines produce more cones. For. Wrkr. U.S. 8 (5): 15.

GERTH, G. 157

1939 Die Liefermöglichkeiten von Gesteinsmehl als Bodenverbesserungsmittel und ihre Bedeutung für die Gesteinsaufbereitungsanlagen (The possibilities for the use of rock dust as a soil improver, and its significance for the rock quarrying industries). Forstarchiv 15: 435-436. fa

From research to date it appears that the powder of basic igneous rocks can be usefully employed in the manuring of seedlings on poor soils, provided the size of the rock grains does not exceed 2 mm. It is estimated that very large quantities of such material are available in Germany for forestry purposes.

GESSEL, S. P., R. B. WALKER, AND G. P. HADDOCK 158

1951 Preliminary report on mineral deficiencies in Douglas fir and western red cedar. Proc. Soil Sci. Soc. Amer. 15: 364-369. aA

Preliminary experiments on the mineral nutrition of certain Pacific Northwest forest tree species have resulted in the following: a. The needs of the species investigated for the usual macro nutrients were verified. b. Characteristic deficiency symptoms for some elements were noted. c. Field fertilization of young stands of Douglas-fir corrected deficiency symptoms and increased nitrogen content of foliage. Phosphorus content was not affected during the first season. d. Romaine lettuce plants grown on two forest soils showed very striking response to phosphorus fertilization. Nitrogen response was correlated with the support of good or poor growth of Douglas-fir under forest conditions. e. Nitrogen content of foliage from trees making poor growth and exhibiting deficiency symptoms tends to be lower than in trees growing more rapidly. Calcium content of western red cedar foliage is higher than Douglas-fir, and older fir needles have a higher calcium content than current growth.

GESSEL, S. P. AND R. B. WALKER 159

1956 Height growth response of Douglas fir to nitrogen fertilization. Proc. Soil Sci. Soc. Amer. 20: 97-100. A

This paper presents the results of initial nitrogen fertilization trials on 15 to 20 year old natural Douglas fir stands growing on poor sites (Site Class IV, V) in western Washington. Annual height growth was used as the criterion of response. On both shallow residual and deep glacial outwash soils response to N was very marked. Larger more vigorous trees responded more than smaller trees and resulted in more rapid suppression of these small trees. Foliage color changed from yellow to dark green after fertilization and before height growth response. Nitrogen content of needles increased from less than 1% to 1.2 to 1.8% after fertilization. Some

aspects of fertilization of forest lands are discussed including use of fertilizers for Christmas tree production.

GLATHE, H. 160

1954 Fosfornäringens betydelse för skogen (Importance of phosphorus nutrition for forests). Växt-närings-Nytt 10: 70-71. (Swedish)

GOODALL, D. W. AND F. C. GREGORY 161

1947 Chemical composition of plants as an index of their nutritional status. Tech. Commun. Bur. Hort., E. Malling 17. 167 pp. fa

A comprehensive survey of the present state of knowledge on the use of plant-analysis method to determine the nutritional needs of plants, including trees. The communication deals with (1) theoretical aspects, (2) selection of technique, method of expression and interpretation or results and (3) the place of plant analysis among methods of nutritional diagnosis. There is a full subject index, an author index to facilitate reference to the numerous authorities quoted, and a bibliography of over 900 items.

GORDIENKO, M. 162

1950 (The influence of chlorides and chlorates on the soil and on the growth of plants). Forstwirtschaft 4: 20-21. a

Nursery stock in Russia was treated with 2-3 applications of Na, K and Ca chlorate (10-20 g./cu.m.) in autumn. This prevented weed growth (couch grass) for several years and caused an increase in the height of trees and the size of the leaves, particularly in oak, maple, ash and locust. Addition of chlorates to the soil also increased NO_3 formation.

GRANT, W. 163

1952 The Dunemann system of nursery practice. Quart. J. For. 46: 247-250.

GUILLEBAUD, W. H. 164

1934 Forest manuring: a survey. Forestry 8: 136-149. L

The results of a large number of manuring experiments on the continent of Europe are discussed and it is shown that the application of inorganic manures has effected a definite improvement in growth in only a small proportion of the experiments. Scots pine

in particular has proved unresponsive to chemical manures. The few spectacular results have been achieved with Norway spruce manured with basic slag (or lime). Attention is also drawn to the probably complex action of most of the commercial fertilizers.

Preliminary data are given regarding recent manuring experiments carried out in Great Britain on different types of peat and podzolized mineral soils. In almost all cases the manure used was basic slag, which was applied at the time of planting to a number of species, including Sitka spruce, Japanese larch, and *Pinus contorta*. Within somewhat narrow limits both as regards soil and species, it appears that manuring with basic slag may be of definite value in promoting the establishment of trees on certain difficult types of wasteland.

GUINAUDEAU, J. 165

1945 Une expérience d'emploi d'engrais sur plantations forestières (An experiment in the use of fertilizers in forest plantations). Rev. Eaux For. 83: 343-351.

HACKMANN, G. 166

1930 Phosphorsäuregehalt von Waldböden und Fichtenwachstum (Phosphoric acid content of forest soils in relation to growth of spruce). Mitt. Forstwirt. Forstwiss. 1: 242-295. Ba

This paper presents the results of an investigation which undertook to determine the quantity of P_2O_5 necessary to insure satisfactory growth of spruce, and the point at which fertilization with P_2O_5 would increase growth. The wood cut in a 100-year rotation removes 50-60 kg. P_2O_5 per ha., and the annual requirements of a Site 2 spruce stand reach 12-15 kg. between 30 and 50 years, and average 9-10 kg. thereafter. The P_2O_5 requirement is influenced by physical condition and acidity of the soil. Phosphate salts are most soluble and most readily assimilated with soil acidity between pH 4.5-6.5, and the quantity of soluble P_2O_5 also depends on the degree of decomposition of the leaf litter. As little as 3.3 mg. soluble P_2O_5 per 100 g. of dry soil will suffice with loamy soils (10-25 sq. m. interior surface) with at least 0.05% $CaO+K_2O$ and pH at least 4.5. With finer soils there should be at least 0.1% $CaO+K_2O$. Ca and K seems to affect the growth only through their effect on the physical condition of the soil. Addition of P_2O_5 probably will not increase growth unless the soil contains less than 6 mg. per 100 g.

On sour soils (pH below 4.0) liming will increase available P_2O_5 by breaking down raw humus.

HACKMANN, G. 167

1931 The fertilization of forests with special reference to phosphoric acid fertilizers. Phosphorsäure 6: 348-368.

HANDEL–MAZZETTI, P. AND W. WITTICH 168

1951 Kalkung des Waldbodens (Liming of forest soils). Öst. Forst-u. Holzwirtsch. 6: 291-292.

HANSEN, T. S. 169

1923 Use of fertilizers in a coniferous nursery. J. For. 21: 732-735. L

At the Cloquet Forest Experiment Station, Minnesota, the following fertilizers were used on white pine and red pine beds in the coniferous nursery in the spring of 1919; the fertilizer quantities given are per bed of 48 square feet; lime 4 lbs. and phosphate ½ lb., sulphate of potash ½ lb., ammonia sulfate 2/10 lb. All the lime was applied one week before sowing; the acid phosphate and sulfate of potash were applied at time of sowing; the ammonium sulfate was applied in solution ½ immediately after sowing and ½ two weeks later. These fertilizers were applied singly and in combinations.

Very little difference was discernible in the general appearance and oven dry weights of the fertilized and unfertilized stock. The results are negative. It seems that coniferous seedlings remove very little plant food from the soil and even in light, sandy soil sufficient plant food is present to produce good seedlings over quite an extended period.

HARTLEY, C. 170

1929 Forest tree seedlings kept from damping-off by aluminum sulphate. Yearb. U.S. Dep. Agric. 1928: 332-334.

HARTMANN, F. 171

1952 a Waldbodenmelioration als Mittel zur Produktionssteigerung (Forest soil improvement as a means of increasing production). Öst. Vjschr. Forstw. 93: 209-218. fa

Discusses the use of different site types of fertilizing with lime or organic material, of green manuring, of burning over the site and of cultivating the soil.

HARTMANN, F. 172

1952 b Forstökologie (The science of forest site types on the basis of ecological factors). ix + 461 pp. Georg Fromme, Wien. fa

Part 4.—Forest soil rehabilitation with special reference to fertilizing (pp. 406-458) deals first with the subject in general, from the point of view of "forest ecology", and then considers the various fertilizers available, and quantities necessary, under the heads: basic silicate rock meal, commercial mineral fertilizers, lime, organic wastes (including brushwood), green manuring, "forest fallow" acid pioneer forest, and burning (the last two categories with and without temporary agricultural use of the land.) A summary of practical conclusions is appended.

HASSENKAMP, W. 173

1941 Die Umwandlung von Rohhumusboden in Mullboden durch Waldfeldbau und Leguminosenanbau (The conversion of raw humus soils into mull soils by cultivation and leguminous crops). Forstarchiv 17: 41-57. fa

The author reports on his experience in the improvement of podzolized silt loams in Hanover. The soils are notoriously lime and colloid deficient and form thick layers of raw humus under a coniferous crop. The operations described included (1) poisoning of *Aira* and ferns with "Anforstan"; (2) burning of clear-felled areas and grubbing of stumps likely to interfere with mechanical cultivation; (3) manuring and heavy liming; (4) rotary cultivation, which broke up and mixed the raw humus with the mineral soil; (5) growing of field crops (rye, oats, barley, and potatoes) for two seasons, which involved a second manuring at the beginning of the second season; (6) planting of a mixed forest crop with pine as the principal species and usually including oak, alder and hornbeam; (7) for further soil improvement, introduction of perennial lupine and broom between the rows of tree seedlings in the year after these had been planted. So far the growth of the plantations established in this manner—the oldest of which are now nine years old—has been excellent, and analysis of the soils indicate that their physical and chemical properties closely resemble those of local mull soils. The cost of the operations was covered largely by the income from field crops.

HAUSSER, K. 174

1950 Ergebnisse der neuesten Aufnahmen des Owinger Forstdüngungsversuches (Results of the most recent surveys of the Owing forest fertilization experiments). Allg. Forst u. Jagdztg. 122: 23-27. fa

Gives results to 1949 of a trial begun in 1906 during the afforestation of pasture land at Owingen bei Hechingen, Württemberg, on Keuper and Lias loams, with pure spruce. The chief result is to show the lasting benefit of fertilizing the site, before planting, with superphosphate or superphosphate plus Kainite (the addition of which gave only a small extra effect); the uncertain effect of $(NH_4)_2 SO_4$; and the insignificant effect, on this site, of liming.

HAUSSER, K. 175

1956 a Ergebnisse von neueren Forstdüngungsversuchen in Württembergischen Schwarzwald (Results of recent forest fertilization trials in Württemberg Black Forest). All. Forstz. 11: 261-264. L. Leyton

Experiments on number of stands on upper and middle Bunter sandstones, poor in nutrients especially P and Ca with raw humus and podzolization. Previous experience suggested large responses to P and Ca in Norway spruce stands. Recent experiments laid down in 1950—one showed marked responses only to N (mainly as nitrochalk).

HAUSSER, K. 176

1956 b Ertragsteigerung in der Forstwirtschaft durch mineralische Düngung (Improvement of forest crops by mineral fertilization). Phosphorsäure 16. 1.

HAUSSER, K AND E. SCHAIRER 177

1953 Ergebnisse von Forstdüngungs-und Meliorationsversuchen in Süd Württemburg (Results of forest fertilization and soil amelioration experiments in South Württemberg). Mitt. württemb. forstl. VersAnst. X: 1

HEARMAN, J. 178

1937 The application of the petiole injection method for the diagnosis of mineral deficiency to a Eucalpt. Aust. For. 2 (2) 23-24. A

It was demonstrated that this method was applicable to eucalypts.

HEARMAN, J. 179

1938 Minor elements and the pine. Aust. For. 3: 24-27. A

Pinus radiata suffering from "rosetting" were stimulated by the injection of manganese sulphate, ferrous sulphate, cobalt chloride, sodium molydbate, and boric acid. The trees were on Wonnerup sand in the Sterling plantation. This soil is very deficient in both major and minor nutrients. The liquid injection method as developed by W. A. Roach was applied to pine trees. The advantage of this method of diagnosis is that it brings a measure of laboratory precision into field experiments.

HEIBERG, S. O. AND D. P. WHITE 180

1951 Potassium deficiency of reforested pine and spruce stands in northern New York. Proc. Soil Sci. Soc. Amer. 15: 369-376. A

Extreme nutrient deficiency of young coniferous plantations of *Pinus resinosa*, *Pinus strobus*, *Picea abies*, and *Picea glauca* was observed on sandy soils developed on a terrace of glacial outwash in the outskirts of the Adirondack Mountains in New York State. Fairly intensive agricultural use for about 100 years prior to 1928 characterized the area.

Deficiency symptoms observed include: 1. General chlorosis followed by browning and finally dying of the needles; 2. Decreased height and diameter growth; 3. Decrease in the number of years that the needles persist on the trees; 4. Shortening of the needles.

Soil mulches of logging debris and forest humus as well as aplications of complete commercial fertilizer produced a strong growth response, whereas a glass wool mulch gave no growth response. Applications of CaO, $NaNO_3$ $(NH_4)_2SO_4$, $Ca_3(PO_4)_2$, and KCl as pure chemical salts in May 1943 and 1946 on *Pinus resinosa* plots resulted in a strong growth response to the KCl only, with a mild response to the $NaNO_3$. Subsequent fertilization of symptomatically deficient coniferous plantations including *Pinus strobus*, *Picea abies*, and *Picea glauca* resulted in a pronounced response of all to potash fertilization even at the end of one growing season.

Chemical analyses of mid-September collected needle tissue showed a strong correlation between increased growth and a high content of K in the tissue. Growth increase was also related to a greater amount of exchangeable potassium in the soil. Current season needles collected from healthy or fertilized *Pinus resinosa* and *Pinus*

strobus in September contained from 0.45–0.74% K. In no case did pines which showed deficiency symptoms contain more than 0.34% K in the current needle tissue and usually less than 0.30%. Deficient specimens of *Picea glauca* and *Picea abies* contained even smaller amounts of K, the current tissue analyzing from 0.13–0.21% K.

Trees fertilized with KCl were strongly preferred for food by the varying hare, *Lepus americanus americanus*.

The increase in annual height growth produced by an application of KCl at the rate of 200 lbs. per acre was from 46% to 104% over the control plots, and the effect of the 1943 potash fertlization still continues in the 1949 growth.

In all samples the K was concentrated in the last year's needles, whereas the Ca content of the needles increased rapidly with age. Over a period of years the K content of the foliage of fertilized *Pinus resinosa* is declining slightly, but the effect of fertilization is still manifest in growth and K content of tissue even after a period of 16 years.

HEIBERG, S. O., E. L. STONE, AND D. P. WHITE 181

1954 Potash and magnesium fertilization of young pine and spruce trees. Pamphl. Coll. For. St. Univ. N.Y. 7 pp. A

This pamphlet summarizes in popular style the recommendations of research results contained in Heiberg and White (1951) and Stone (1953). Of particular interest are two large color plates showing potassium deficiency of white spruce and magesium deficiency of white pine.

HELLMERS, H., J. F. BONNER, AND J. M. KELLEHER 182

1955 Soil fertility. A watershed management problem in the San Gabriel mountains of southern California. Soil Sci. 80: 189-197. fa

Pot and field trials made to test the reactions of 5 chaparral species, including *Pinus coulteri*, *Pseudotsuga macrocarpa* and *Quercus chrysolepis*, on three local soil types, when N, P, K, Ca and five minor elements are added, indicate the possibility of interrupting the sparse cover, rapid-erosion cycle by increasing the fertility of the soil. N was here particularly effective. The intake of P is probably limited by critically low rainfall. Tables show the weight of total shoot growth of seedlings raised in pots and the weights of the longest terminal shoots in the field plots under the treatments.

HELMS, J. 183

1911 Nogle gødningsforsøg i sygnende Grankulturer paa Hedejord (Some fertilization experiments in stagnating spruce plantations on heath soil). Tidsskr. Skovvaes. 23: 66-85. (Danish)

HELMS, J. 184

1922 Grankulturerne i Sevel og Borgbjerg plantager (The spruce plantations at Sevel and Bordjerg). Forstl. Forsøksv. Danm. 6: 87-136. (Danish w/German summary)

HEPTING, G. H., T. S. BUCHANAN AND L. W. R. JACKSON 185

1945 Little leaf disease of pine. U.S. Dep. Agric. Circ. 716 15 pp. fa

An account of investigations on a disease of *Pinus echinata*, and to a lesser extent of *P. taeda*, the symptoms of which are the formation of fewer and shorter needles resulting from progressive annual shortening of twig growth and ending in premature death of trees of all classes and ages over 20 years. The disease in not directly due to weather, soil moisture, or deficiency in phosphorus and potassium; the many other possible factors are numerated for further research. Prompt harvesting of affected trees is the only treatment at present indicated.

HERBERT, P. A. 186

1926 Fertilizing the forest nursery. Quart. Bull. Mich. agric. Exp. Sta. 8: 188-192.

HERBERT, P. A. 187

1927 A laboratory study of black spruce. J. For. 25: 437-442. Ba

Growth of *Picea mariana* seedlings in various nutrient solutions and other media is described.

HEUSON, R. 188

1938 Bodenkultur der Zukunft (Soil cultivation of the future). 96 pp. J. Neumann, Neudamn. fa

There are in Germany at present one million hectares of waste land and at least three million hectares are gradually becoming derelict. A large proportion of the waste land is the result of con-

tinuous removal of forest litter in the past or of prolonged cropping without due attention to the restoration of soil fertility.

The following procedure for reclaiming waste land is recomended:

1. Pedological survey.

2. Cultivation. Soils of waste lands which in the past have been either cultivated or under forest usually have an isolating layer of powdery sterile topsoil, which must be mixed with the underlying mineral soil. Iron deposits and layers of extremely compact gravel and sand must be loosened. Where different mineral soils are found in sharply defined layers, a mixture should be aimed at. For reasons of economy, cultivation will generally have to be in strips.

3. Restoration of fertility. Most waste lands are extremely poor in nitrogen, humus, and bacteria, and whatever mixture of species for afforestation should be decided upon, it is essential to include a soil-improver. The author achieved remarkable success with *Alnus glutinosa*, in mixture with other broad-leaved trees and with *Pinus sylvestris* respectively, and considers it a much more reliable soil-improver for waste lands, including dunes, than *A. incana*. In some cases manuring may be justified. The use of a mixture of chalk and soft brown coal (a soft form of lignite occuring in Germany) inoculated with bacteria is recommended.

Large scale reclamation of waste land can be achieved only by the State or with State assistance and under State control.

Hilf, H. H. 189

1938 Die Düngung mit Basalt-Abfällen (The manuring [of poor sand] with basalt grit). Forstarchiv 14: 93-101. fa

In a previous paper the author described the success of preliminary experiments on the manuring of poor sands with waste basalt from road-metal quarries. The present article is a progress report on experiments on the Finowtal valley sands. The area, which had been ploughed and planted with pine in 4:1 mixture with other conifers and hardwoods, was divided into 12 experimental plots and treated with graduated amounts of basalt. The beneficial effect of basalt in improving water retention and supplying deficient mineral nutrients brought about a striking increase of growth in most of the hardwoods. A small improvement was also noticeable in the conifers, and it is expected that they will benefit indirectly from the accumulation of hardwood litter and humus. Costs of

material and transport are discussed. The most suitable material is said to be a 9:1 mixture of basalt grit and basalt dust. Present experience suggests that the required amounts of basalt are as follows: 1-3 kg. per planting hole for larger plants, 0.2 kg. for one year old seedlings, and layers 1 cm. deep in nursery plots. It is suggested that suitable fertilizers may also be obtained from other minerals such as gabbro and diabase.

Hilf, H. H. 190

1951 Weiserpflanzen für den Fortskulturbetrieb; Folgerungen aus Düngungsversuchen mit schnell-wachsenden Holzarten (Indicator plants for forest plantation practice: conclusions from fertilizer trials with quick growing tree species). Forstarchiv 22: 43-50. fa

Gives examples, from German trials, of the sensitivity of hybrid black poplars and osier willows to adverse soil conditions and especially of their rapid response to soil improvement (by liming, fertilizing, addition of humus), to illustrate the theme that fast growing tree species naturally adapted to rich alluvial soils can be employed as indicators which will give measurable results in a short time. They may be used to test (a) the suitability of soils for their own growth and for that of other relatively exacting species, and (b) the effects of composition and rates of application of fertilizers and other soil amendments, and of soil cultivation. In tests of races, etc., individual strains may react to fine differences in site factors and so make possible a closer appreciation of the soil and its treatment on the one hand, and on the other, the suitability of the individual strains for particular sites.

Hilf, R. B. 191

1949 Düngung der Kiefernkultur (Fertilizing of pine plantations). In: H. Hesmer (ed.), Technik der Kiefernkultur. viii + 185 pp. M. and H. Schaper, Hannover.

Hitier, H. 192

1947 La fumure du peupler est-elle rendable? (Is it economic to apply fertilizer to poplar?). Potasse 1947: 186-188. fa

Report on experiments in applying artificial fertilizers to poplar cuttings in a nursery and to transplants in the field. The nursery treatment consisted of a preliminary application of 300 kg. of slag 16-18%, and 300 kg. of KCl 49%, and an application, immediately

before planting, of 150 kg. cyanamide, or 120 kg. sulphate of ammonia, or 150 kg. calcium nitrate; also, in the 2nd and 3rd years, surface applications of 100-125 kg. cyanamide.

In the field experiments (156 plants/ha.) one kg. of a complete fertilizer (7-17-24) was applied to each tree in the 2nd and 3rd years. At 13 years the mean g.b.h. was 0.75-0.95 m., mean height of a clear bole 18 m., compared with 0.50-0.70 m. and 15-17 m. respectively for untreated trees at 15 years. It is concluded that treatment is economically practicable in view of the increased growth rate and superior quality of timber obtained.

HOBBS, C. H. 193

1944 Studies on mineral deficiency in pine. Plant Physiol. 19: 590-602. fa

An account of greenhouse experiments with four species of pine seedlings (pitch, red, white, and shortleaf pines) grown under conditions of deficient nitrogen, phosphorus, potassium, and magnesium respectively. The symptoms caused by the various types of mineral deficiency are described. Nitrogen, phosphorus, and potassium deficiencies were accompanied by greatly reduced growth; the effect of magnesium deficiency was less marked.

HOERTL, E. J. 194

1955 New horizons in the application of chelation to agriculture. Down to Earth: 1955: 6-7.

HOLMES, G. D. AND R. FAULKNER 195

1953 Experimental work in nurseries. Rep. For. Res., Lond. 1951-52: 15-27. fa

The restoration of fertility by partial sterilization of the soil was further investigated. Soil-steaming experiments were confined to investigating the best and cheapest techniques for steaming, the use of a hood being found the most practicable, steam being passed until the soil reaches 180°F. at a depth of 6 in. Attempts at improving the efficiency of partial sterilization with formalin by sealing the soil in various ways gave inconclusive results. It was found, however, that the amount of water used to dilute a given amount of formalin was important, and that less than one gallon of water/sq. yd. (containing 0.1 gal. commercial formalin) resulted in a smaller growth response by the seedlings. Soil acidification at Widehaugh nursery in Northunberland, carried out in 1950 by various

methods, had no residual effect on the height growth of seedlings from 1951 sowings.

Trials were carried out with various straw and sawdust composts, using $(NH_4)_2 SO_4$, formalized casine, and spent hops, as sources of N to activate the breakdown of organic matter. On heathland and woodland soils, all composts gave improved growth of seedlings, though how much of this was due to the nitrogenous activators is not clear. Responses on older established nursery soils were insignificant. In some mulching experiments on heathland soils, comparing a bracken mulch with an inert cellulose mulch, the former gave an increase in growth, while the latter slightly depressed it, suggesting that the main effect of bracken mulch is due to the nutrients leached out of it. A long-term fertility demonstration at Teindland and heathland nursery in Morayshire, in which regimes of compost and fertilizer applications, separate and in combination, are compared with unmanured controls, was cropped for the second year and showed best results from fertilizers without compost. A similar demonstration, with the added factors of partial sterilization and green cropping, has been started at Newton Nursery near Elgin, an old established nursery on agricultural soil. Here, formalin treatment had the greatest single effect; fertilizers produced considerable benefit, but neither green crop nor compost treatments have so far had any effect on mean height as compared with controls.

An old green-cropping experiment at Kennington nursery (Oxford) showed no improvement in fertility on plots that had been under grass ley for several years, compared with those continuously cropped with Sitka spruce. Plots that had lain fallow continuously did, however, show significantly greater total production of Sitka spruce seedlings. At Wareham heathland nursery, incorporation of green crops had a depressing effect on seedling growth in the subsequent year.

Holmes, R. S. and J. C. Brown 196
1955 Chelates as correctives for chlorosis. Soil Sci. 80: 167-179.

Holsoe, T. 197
1941 Fertilizing planting stock on eroded soils. J. For. 39: 69-70. fa

An experiment to determine the effect of a 4-12-4 nitrogen, phosphorus, potash fertilizer on tree growth on eroded soils showed

that, even when fertilizer was placed 6 in. below the soil surface, weed growth was increased and only fast-growing tree species such as black locust could successfully compete with it. Slow-growing, intolerant tree species should not be fertilized during the year of planting unless weed competition can be prevented.

HOWELL, J., JR. 198

1932 The effect of the concentration of the culture solution on seedlings of ponderosa pine. J. For. 30: 829-830. L

The ponderosa pine seedlings respond to the concentration of the culture solution, thus, the results of this experiment tend to show that the concentration of the soil solution may influence to some extent the type of root system that a plant will produce.

HUBERT, H. 199

1939 La fumure des peupliers (Manuring of poplars). Potasse 13: 58-59. fa

Young trees responded to complete manure, gaining 10 per cent in diameter over controls.

HUCHLER, H. 200

1956 Stickstoffdüngungsversuche in Tannenalthölzern (Experiments with nitrogen fertilization in mature European fir stands). Allg. Forstz. 11: 157-158.

HUGHES, H. 201

1949 Sawdust as a compost ingredient. Quart. J. For. 43: 77-78. fa

It has been observed that conditions dangerously toxic to plants arise in the soil where certain fungal activity is present which is able to produce complex organic acids that are in turn transformed into sulphides. Such activity has been found when sawdust derived from hardwood trees has been mixed with the soil and has remained there for a long time owing to its slow rate of decomposition. It appears that when such fungal spores are present in the soil, and under suitable conditions of environment and climate, certain hardwood sawdusts can promote their growth. Conifer sawdusts apparently do not share this property. Considerable field research is necessary before any particular hardwood species can be identified as responsible.

Hussain, S. M. 202

1952 *Fomes annosus* (Fr.) Cke., a common root-rot. Pakist. J. For. 2: 216-220. fa

F. annosus has been found for the first time in the Murree Hills, Pakistan, attacking *Pinus excelsa* and *Aesculus indica*. It was observed that if the soil pH was raised by liming to 7.5 or 8, sporophore production by this fungus was markedly reduced.

Hutchinson, H. P. 203

1939 The manuring of cricket-bat willows. A. R. Long Ashton Res. Sta. 1938: 249-253. fa

Trees grown on drift loam in a non-flooding permanent meadow were supplied with sulphate of ammonia at the rate of 2 lbs. to each tree. The fertilizer was applied in February, when root growth begins in this locality. The increase in timber value due to 42 lbs. of the fertilizer was 4,325 cu in. On the basis of previous values for the timber and fertilizer, 3s., 6d. worth of fertilizer produced 52s. 6d. worth of timber.

Ibberson, J. E. and H. Streater 204

1952 White pine blight responds to fertilizer applications. Penn. For. Wat. 4: 30-31. fa

White pine blight, a disease of unknown origin, occurs on *Pinus strobus* of all ages, from Canada to Georgia. An experiment has been started in Cook Forest, Pennsylvania, to test the response of diseased trees to various fertilizer treatments. The disease appeared to respond very definitely and rapidly to applications of complete fertilizer (10-6-4) at a rate of 1 to 2 lb. per in. d.b.h.; 3lb./in. d.b.h. was apparently an overdose and had a toxic effect on the trees. The next best response was obtained by applications of 1 lb. Ca $(OH)_2$/in d.b.h., but this stimulation would probably soon wane, and applications of balanced fertilizer over a period of time should prove more effective. None of the applications of trace elements gave positive results.

India-Burma Forestry Research 205

1952 Aids to germination. For. Res. India. 1947-48 (II): 40.

IRISH, C. F. 206

1929 The process of aeration and fertilization of tree roots by means of compressed air. Proc. nat. Shade Tree Conf. 5: 35-36.

JACOBS, H. L. 207

1937 Fertilizer formulae—tree responses. Proc. nat. Shade Tree Conf. 13: 51-63.

JAEGER 208

1956 Forstdüngung mit Thomasphosphat in der Waldgenossenschaft Stellheide (Fertilization in forest with Thomas phosphate in the Stellheide forest community). Forst-u. Holz 11: 256-257.

JANSSEN. S. L. 209

1948 Isotopmetodiken som hjälpmedel inom växtfysiologien, markläran och gödsellären (Isotope tracer methods as an aid in plant physiology, soil science and fertilizing). K. LandtbrukAkad. Handl. Stockh. 87: 370-392. (Swedish w/ English summary) fa

A review of the literature.

JENSEN, P. 210

1952 Anvendelse af Kunstgødning it Skoybruget (The use of artificial fertilizer in forestry). Hedeselsk. Tidsskr., Aarhus 73: 63-65. (Danish) fa

Norway spruce (2-0 stock) planted from 1949 to 1951 was treated in 1951 with "Nitrophoska" at the rate of four sacks (cost Kr. 96)/10 ha. Wages amounted to Kr.100, giving total cost of about Kr.20/ha. A very much increased leader growth was obtained. A dose of 12-15 g. per plant was given. Application from mid-April to mid-May is recommended.

JENSEN, P. 211

1953 Anvendelse av Kungstgødning i Skovbruget (Use of artificial fertilizers in forestry). Hedeselsk. Tidsskr., Aarhus 74: 79-81. (Danish) fa

Further measurements on Norway spruce confirm the increased growth obtained by treatment with "Nitrophoska". Japanese larch

planted with the spruce appeared not to benefit at all from the fertilizer.

JESSEN, W. 212

1938 a Über die Wirkung chlorhaltiger Kalisalze auf das Wachstum von verschiedenen Holzarten im Gefässversuch (The effect of potassium salts containing chlorides on the growth of various tree species in pots). Bodenk. u. Pfl-Ernähr. 7: 62-77.

JESSEN, W. 213

1938 b Phosphormangelercheinungen bei verschiedenen Holzarten (Phosphate deficiency symptoms in different tree species). Phosphorsäure 7: 263-270.

JESSEN, W. 214

1939 a Kalium- und Magnesiummangelerscheinungen und Wirkung einer Düngung mit Kaliumchlorid und Kalimagnesia auf das Wachstum verschiedener Holzarten (Potassium and magnesium deficiency symptoms and the effect of fertilizing with potassium chloride and sulphate of potash magnesia on the growth of various tree species). In: Magnesium ein Pflanzen Nährstoff. pp. 207-212. Deutscher Innen- und Aussenhandel Bergbau, Berlin.

JESSEN, W. 215

1939 b Kalium- und Magnesiummangelerscheinungen und Wirkung einer Düngung mit Kaliumchlorid und Kaliumagnesia auf das Wachstum verschiedener Holzarten (Potassium and magnesium deficiency symptoms and the effect of fertilizing with potassium chloride and sulphate of potash magnesia on the growth of various tree species). Ernähr. Pfl. 35: 228-230. fa

Seedlings of larch, fir, and spruce were grown on Dörentrup quartz sand pretreated with hot 10 per cent hydrochloric acid to remove any nutrients present. Seven treatments were included in the experiment: (1) no fertilizer, (2) manuring without potash, (3) complete fertilizer with low potash application as KCl, (4) complete fertilizer with triple potash application as $(KCl)_3$, (5) complete fertilizer with low application of potash magnesia (KMg.),

(6) complete fertilizer with triple application of potash magnesia $(KMg)_3$, (7) manuring without magnesia.

Nutrients were applied in solution. Fir and spruce seedlings receiving no potash showed a chlorotic discoloring of the needles and retardation in growth within three months of seeding. In five months the needles of the larch began to yellow and the spruce and fir seedlings showed brown and reddish purple discoloration. Spruce and fir seedlings receiving no magnesium gave indications of this deficiency towards the end of the growing season, the needles first turning yellow and then reddish brown at the tips. Applications of potash in both forms resulted in considerable increases in yields of dry matter.

JESSEN, W. 216

1939 c Die Wirkung von Rohphosphat auf das Wachstum der Holzarten in sauren Waldböden (The effect of rock phosphate on the growth of tree species on acid forest soils). Bodenk. u. PflErnähr. 13: 249-256. fa

In Neubauer pot experiments with two acid soils (mortar sand and diluvial sand), raw phosphate was as effective as superphosphate or basic slag (Thomas process) in increasing the dry weight and P_2O_5 absorption of larch seedlings. Raw phosphate had little effect when applied in combination with liming. The experiment suggests that phosphates of low solubility might find a useful application in the manuring of acid forest soils.

JESSEN, W. 217

1940 Über die Wirkung chlorhaltiger Kalisalze auf das Wachstum von verschiedenen Holzarten im Gefässversuch (The effect of potassium salts containing chlorides on the growth of various tree species in pots). Ernähr. Pfl. 36: 67-68.

JESSEN, W. 218

1941 Die Wirkung von Rohphosphat auf das Wachstum der Holzarten in sauren Waldböden (The effect of rock phosphate on the growth of tree species on acid forest soils). Bodenk. u. PflErnähr. 25: 31-34. fa

The suitability of raw phosphate as a fertilizer for acid soils, demonstrated in previous trials with larch, was confirmed by fresh tests with Scots pine. Using unlimed soil, the effect of the raw

("Algier") phosphate on dry weight and P_2O_5 uptake of the seedlings was equal to that of superphosphate or basic (Thomas) phosphate, but when combined with liming it was less effective than the two latter.

JOBLING, J. 219

1953 Establishment of poplars. Rep. For. Res., Lond. 1951-52: 72-75. fa

An experiment was designed to show what type of planting stock produces the best poplar plantations. The types tried were: (1) 1-year rooted cuttings, (2) stumped 1-year cuttings lined out in the nursery for one year, (3) stumped 1-year cuttings lined out for two years, and (4) unrooted setts, using *Populus serotina* (both ordinary and narrow-crowned varieties), *P. gelrica* and *P. robusta*. Trials were made on three different site types. The different treatments produced virtually the same results on all sites. *P. serotina* narrow-crowned variety and *P. gelrica* survived better on all sites than the other two.

Of the types of planting stock tested, (2) gave best survival and height growth; (4) generally the poorest survival; (1) better survival and height growth than either (3) or (4); (3), a large and expensive type of plant to produce, were not significantly more successful in the field than (4), which are relatively cheap.

In manurial experiments, applications of N produced the greatest effect; responses were also obtained from K.

JOHANSEN, R. W. 220

1955 The effects of certain nursery treatments and site preparations on the vigor and survival of longleaf pine (*Pinus palustria* Mill.) in the deep sands of the Carolinas. M. S. thesis, N.C. St. Coll., Raleigh.

JØRGENSEN, C. A. AND C. TRESCHOW 221

1948 Om bekaempelse af rodfordaerver (*Fomes annosus*) ved fladrodesplanting og ved kalk-og fosfattilskud (On the control of root-rot and butt-rot caused by *Fomes annosus* by superficial planting and application of lime and phosphate). Forstl. Forøksv. Danm. 19: 253-284. (Danish) fa

The authors review literature on *F. annosus* with chief reference to their earlier work, which suggested that means of controlling

attacks on Norway spruce in Denmark might be found in (a) raising the pH of the soils above 6.0, beyond which value growth of the fungus in culture had declined rapidly, and (b) finding a planting method that discourages the formation of a tap root through which, on its death at 20-30 years of age, the fungus is able to invade the tree.

Field experiments, described fully in this paper, were started in 1942, to examine the effects of lime and phosphate applications to the planting hole, and to compare the Norwegian method of superficial planting with roots spread flat out, with ordinary planting in well dug holes. As *Fomes* attacks do not usually become prevalent in plantations younger than 25-30 years, decisive results cannot be obtained before that age. Meanwhile, preliminary results have shown that the pH can be considerably raised, for a time at least, by local applications of lime or phosphate and that flat-rooted planting will work under Danish conditions, giving a flat superficial root system without a tap root.

KARLBERG, S. 222

1954 Några skogliga växtnäringsförsök preliminär redogörelse (Preliminary report of some plant nutrient experiments). Växt-närings-Nytt 10: 8-13. (Swedish) a

One year poplar seedlings on a sandy loam soil responded only slightly to PK, and more vigorously to NPK.

KARLSSON, K. G. .. 223

1945 Om gödsling i fasta plantskolor (Manuring in permanent nurseries). Skogen 32: 131-132. (Swedish) fa

An account is given of the results obtained during twenty years' work, including 300 manurial trials, in the nursery at Ed, near Östhammer in the province of Stockholm. Trials were made with green manures, with the cultivation of potatoes, and with artificial fertilizers of all kinds. In 1930, more than 6,000 earthworms were introduced into the soil.

Green manuring, which proved to be very costly, did not give any appreciable results. Of the artificials only the nitrogen fertilizer "Floranid" gave positive results. The earthworms appear to have had a good effect on the soil. Compost manuring gave good results: pine plants from compost manured beds showed a markedly better

"trunk form" than those which had been grown in soil treated with other types of fertilizer. Detailed instructions are given for the making up of a compost heap.

Artificial watering during dry periods in the early summer resulted in plants showing greater susceptibility to frost and becoming somewhat lighter in color, although there was no deficiency of nitrogen, and in increasing weeds to an alarming extent even with systematic weeding.

KEPHART, L. W. 229

1949 Economic poisons in fertilizers. Rel. Bur. Plant Ind., Dep. Agric. 5 pp. fa

Discusses the pros and cons of the use of 2, 4-D fertilizer mixtures, which have hitherto been used almost exclusively on lawns and golf links.

KESSELL, S. L. 225

1943 The nutrition of the forest crop. Aust. For. 7: 4-21.

KESSELL, S. L. AND T. N. STOATE 226

1936 Plant nutrients and pine growth Aust. For. 1: 4-13.

KESSELL, S. L. AND T. N. STOATE 227

1938 Pine nutrition. An account of investigations and experiments in connection with the growth of exotic conifers in Western Australian plantations. Bull. For. Dep. W. Aust. 50, 45 pp. Ba

The government of Western Australia has planted 11,400 acres of pines, mainly *Pinus radiata* and *P. pinaster*, during the last 15 years. The plantations were studied to ascertain the reason for unsatisfactory growth in certain localities. Depth, physical properties, and moisture-retaining capacity of the soil are of minor importance compared with soil fertility. *P. radiata* requires considerably more plant nutrients than *P. pinaster*. The P_2O_5 content of the soil is a good indicator of the suitability of the site for either pine, provided the soil has not been intensively cultivated or pastured. The best remedy for poor growth is cultivation, with application of superphosphate at the time of and after planting. Young pines should be sprayed with solutions of Zn salts.

Kocherina, E. I. 228

1940 (Changes in the physical properties of the soils of the Solonetz complex in the chestnut zone under the influence of chemical and biological ameliorative measures under conditions of irrigation). Trans. Dokuchaev Soil. Inst. 24: 181-204. (Russian w/English summary)

Koderle, J. K. 229

1865 Die Grundsätze der künstlichen Düngung im Forstkulturwesen (The principles of [the use of] artificial fertilization in forestry). Wien.

Konias-Mottl, 230

1951 (Results of the amelioation of degraded forest soil under pine stands on diluvial sand at Opocno). Čsl. Les 31: 419-420. (Czech) fa

To improve the poor, dry mineral soil, degraded by pine monocultures, it is intended to introduce into the stands up to 20% of soil-improving handwoods (mainly *Tilia cordata* and *T. platyphyllos*, also beech and hornbeam), and 40% of oak, leaving only 40% of pine. The total regeneration period is to last 40 years. The first measure consists in winter clear-felling of trees in circular areas of ca. 20 m. diameter (roughly the height of the trees), the centers of the circles forming squares of 60-65 m. side. After some ten years, similar clear fellings are made in the center of the squares, so that ultimately the centers of adjacent circular areas are ca. 45 m. apart. In summer, the soil in the felled areas is cultivated, and 70 kg. of ground gabbro-diorite quarry waste and 70 kg. of ground limestone are used for covering each area of 20 m. diameter. Birch is sown late in summer; next year, 1 to 2 year old *Alnus glutinosa* is planted at 2.4 × 2.4 m. spacing and 2-year-old spruce at 1.2 × 1.2 m. When these subsidiary species are 30 cm. high 1 to 2 year old lime, beech and hornbeam are planted at 1.2 m. spacing. Oak is sown on an annular strip ca. 7-10 m. broad round the circular area. Sound pine stems are not felled.

Koning, de 231

1930 De invloed van kunstmest op den groei in de houtmassa van dennenbosch (The effect of artificial fertilizers on the increase of wood volume of pine forests). Tijdschr. ned. Heidemaatsch. 48

Kop, L. G. 232

1951 Een en anderover de groei van fijnspar en Douglas in Drente (On the growth of Norway spruce and Douglas fir in Drente). Ned. BoschbTijdschr. 23: 75-79. (Dutch w/ English summary) fa

Afforestation on the heaths of Drente was started some 30 years ago. Measurements have been made on sample plots between 19 and 27 years old to determine the effect of different soil treatments. Groups 1 and 2 were given the same preliminary soil treatment—ploughing to a depth of 50 cm., dressing with K and P fertilizers, and disk harrowing; group 1 plots were grown under lupin for a year before planting and group 2 plots were given a dressing of compost about 10 years after planting. Group 3 plots were on old agricultural land. Average height and volume increment were better on group 2 and 3 than on group 1 plots. The difference was far more evident for Douglas fir than for spruce. It seems possible that the favorable results of compost treatment are largely related to moisture, because stands which had not been dressed with compost, but on which moisture conditions were favorable, also showed good growth.

Kopitke, J. S. 233

1941 The effect of potash salts upon the hardening of coniferous seedlings. J. For. 39: 555-558. faA

The effect of potash fertilization upon the properties related to hardening of white spruce, red spruce, and white pine seedlings was studied in quartz sand cultures and on sandy nursery soils located in northern Wisconsin, Application of potash fertilizers promoted the accumulation of simple and invert sugars in the tissue of seedlings. It increased the content of total solids and the osmotic pressure, and lowered the freezing point of the expressed sap. All of these changes indicate a marked improvement in the ability of nursery or planting stock to withstand forest injury. Frequent analyses of nursery soils and timely correction of potash deficiency are recommended as a prerequisite for production of frost-resistant nursery stock. Applications of fertilizer in amounts higher than 300 lbs. of K_2O per acre had a pronounced unfavorable effect.

Korstian, C. F., C. Hartley, L. F. Watts, and G. G. Hahn 234

1921 A chlorosis of conifers corrected by spraying with ferrous sulphate. J. agric. Res. 21: 153-171.

Köstler, J. 235

1956 Waldbau (Silviculture). Translation by M. L. Anderson, xvi + 416 pp., Oliver and Boyd, London.

Kramer, P. J. 236

1951 Effects of respiration inhibitors on accumulation of radioactive phosphorus by roots of loblolly pine. Plant Physiol. 26: 30-36. faA

The effects were studied of 0.01 M NaN_3, 0.005 M NaF and 0.025 M malonic acid, at various pH values, on the accumulation of P^{32} by mycorrhizal and non-mycorrhizal roots of *Pinus taeda*. Roots were exposed to the inhibitors for an initial period of ca. 1 hr., and then exposed for 3 hr. to the inhibitor plus P^{32} to produce an activity of about 300 microcuries/liter. NaN_3 reduced accumulation more in non-mycorrhizal than in mycorrhizal roots at all pH values. The inhibition was almost complete at pH 4.7 but much less at pH 5.7. NaF almost completely inhibited accumulation at the lower pH but increased it above the control rate at the higher pH. Malonic acid did not significantly reduce accumulation at the lower pH, but increased it above the control rate at the higher pH. The pH of the system has a marked effect on the action of all three inhibitors. In general, pine roots seem to react to respiration inhibitors in about the same manner as barley and tomato roots. It was concluded that, although both types of pine roots contain a respiratory enzyme system sensitive to NaN_3 and NaF, that of non-mycorrhizal roots is much more sensitive. It also appears that the two types of roots are somewhat different physiologically.

Kramer, P. J. and K. M. Wilbur 237

1949 Absorption of radioactive phosphorus by mycorrhizal roots of pine. Science 110: 8-9. aA

No direct measurements of mineral absorption by mycorrhizal roots have been made, the conclusions concerning their high efficiency as absorbing structures being based on differences in growth and in chemical composition of plants possessing them as compared with plants lacking them. By immersing roots in radioactive phosphorus and preparing radioautographs, it is possible to obtain direct evidence concerning the relative amounts of phosphorus absorbed by various regions of roots. the results of these experiments show that mycorrhizal portions of roots of pine can accumulate much

more phosphorus than non-mycorrhizal portions. Root segments bearing short, unbranched, pseudo-mycorrhizal lateral roots appear to accumulate more phosphorus than typical unsuberized root tips. It seems that mycorrhizal roots have not only a greater absorbing surface but they possibly also have a greater capacity per unit of surface to accumulate phosphorus than non-mycorrhizal roots. Apparently in pine roots, the region of maximum intake of minerals is not the root tips, as in roots of herbaceous plants, but the older regions where mycorrhizal or pseudomycorrhizal branch roots have developed.

KREAG, K. K. 238

1939 Chlorosis studies in Michigan. Trees Mag. 2: 13.

KREAG, K. K. 239

1940 Nature and control of shade tree chlorosis in Lansing, Michigan. Proc. nat. Shade Tree Conf. 16: 32-38. fa

Chlorosis of shade trees in this locality is due mainly to deficiency of minor soil elements. Soil treatment with iron sulphate and powdered sulphur has been successful under certain soil conditions, and application of manganese sulphate to the soil has proved effective in many but not nearly all cases. Good results have been obtained by treating trees with sprays containing iron sulphate or manganese sulphate, but the improvement lasts only one season and reliable soil treatments giving more permanent results are the real desideratum.

KRUMM, C. J. 240

1941 The composition and effects of fertilizers and composts in forest nurseries. M. S. Thesis, Univ. Wis. Library, Madison.

KRUMM, C. J. 241

1946 Review of literature on composted fertilizers. Tech. Notes Wis. Conserv. Dep. 26.

KRUPENIKOV, I. A. 242

1940 Soil and salt resistance of *Betula Kirghisorum*, birch of Kirghizia. C. R. Acad. Sci. U.R.S.S. 26: 706-708.

KRUPENIKOV, I. A. 243

1943 (The growth of pines (*Pinus sylvestris*) on soils containing salt). Dokl. obsch. Sobr. Ak. Nauk. S.S.S.R. 41: 273-276. (Russian w/English summary)

LAGERROTH, S. 244

1954 Skogsgödslings försök pa Aske (Forest fertilization experiments at Aske). Växt-närings-Nytt 10: 52-53. (Swedish)

LANQUIST, K. B. 245

1954 Use of overhead irrigation lines to apply liquid fertilizers and weedicides. Tree Plant. Notes 16: 2-4

LARSEN, J. A. AND W. G. STUMP 246

1939 Some experiments with fertilizers for evergreen seedlings. Iowa St. Coll. J. Sci. 13: 293-311. fa

Nursery and greenhouse experiments with various fertilizers on the production of seedlings of white pine, Douglas fir, Norway spruce.

LAUDELOT, H. 247

1950 Étude pédologique d'un essai de fumure minérale de l'Elaeis à Yangambi (Pedological study of an experiment in applying mineral fertilizer to *E. guineensis* at Yangambi). Publ. Inst. nat. agron. Congo belge (Série sci.) fa

The composition of the fertilizer used in this experiment (values in gram equivalents) was: Ca 143, Mg 20, K 44, NO_3 44, PO_4 160, SO_4 42. The minerals were applied on 2×1 m. plots between the rows of Oil Palms at irregular intervals over a period of a year. Sampling was carried out two years after the 1st, and 1 year after the last dressing. The following results were observed: (1) Total soluble salts increased sharply down to a depth of 60 cm. (2) The pH value of the soil had slightly increased in the surface horizons and markedly declined in the subsoil. (3) Total exchange capacity had increased strongly at all levels from 0 to 60 cm. (4) There was no change in the total N content. (5) Some Ca and Mg had been fixed in the topsoil, but leaching had been appreciable. (6) No K had been fixed in a non-exchangeable form. Because of this and the presence of Ca neutral salts, losses of K by leaching were severe. It is suggested that liming, to increase the amount of ab-

sorbed Ca when K salts and neutral Ca salts are applied simultaneously, would substantially reduce loss of K by leaching.

LEININGEN, W. G. 248

1931 Forstwirtschaftliche Bodenbearbeitung, Düngung und Einwirkung der Waldvegetation auf den Boden (Forest soil cultivation, fertilization and influence of the forest vegetation on the soil). In: Blanck's Handbuch der Bodenlehre 9: 348-496. Springer, Berlin.

LEININGEN-WESTERBURG, W. 249

1935 Über Düngung in forstlichen Betrieben (Fertilization in forestry). Forstwiss. Zbl. 74: 561-569, 593-602.

LENT, J. 250

1928 Der Owinger Forstdüngungsversuch (The Owinger forest Fertilization experiments). Z. Forst.-u Jagdw. 60: 641-659. Ba

Two experimental rows of spruce were established on waste land at Owing in 1906 and 1907. Final measurements were made in 1927-28. The results indicate the outstanding value of phosphoric acid (Thomasmehl) manuring. Kainit probably may be used successfully, but other fertilizers, such as lime, had no effect.

LEVY, B. F. G. 251

1947 Tree injection I. The estimation of dosage in relation to tree size. II. Methods of overcoming resistance to absorption of liquids. III. Re-invigoration of debilitated trees. Rep. E. Malling Res. Sta. 1946: 99-112. fa

I. Previous methods for estimation of dosage and the need for a reliable method are discussed. Tree size, as measured by the cross sectional area of the stem, is compared with dosage on four sets of trees. From these it is concluded that the maximum safe dose was approximately 0.5 g. of salt per sq. cm. of cross-sectional area, and that this could be used as a basis for the estimation of dosage in the field. A trial of this method, on a further set of 132 trees, supported this conclusion. Recommendations are given for the practical application of the method.

II. It is pointed out that trees will sometimes not absorb liquid when injection is attempted. Three methods of overcoming this

are described: raising the reservoir to give a head of pressure, using a force pump, using the pump followed by injection in the normal way. A method of measuring rate of absorption during injection is described.

III. Apple trees severely affected by potassium deficiency were injected in midsummer with a "complete" nutrient rich in potassium. In the same summer, incipient fruit buds were stimulated into vegetable growth. Next spring, on the treated trees there were decreases in the proportion of fruit to wood buds, in die-back, in "ghost-blossoms", and later in leaf scorch. The experiment does not allow for any final conclusions, but it does show that benefit can be derived from injections in midsummer despite growth having practically ceased. The amount of deterioration was reduced, but neither the cropping nor the extension growth was materially increased in the year of injection or the next. However, the injected trees seemed likely to produce better growth and crops the next year, since they possessed more bearing wood and healthier foliage.

LEYTON, L. 252

1950 The growth and mineral nutrient relationships of trees growing on *Calluna* dominated sites. Abstr. Int. bot. Congr. 7th Stockh. pp. 1. fa

A study of rooting habits and mineral nutrient relationships in coniferous species growing on Calluna-dominated sites. Experiments were made to compare the effects of screefing and those of graded applications of P fertilizer on the growth of spruce and pine on such sites. The results suggest that the growth of spruce is intimately connected with its N status and that there is a close relationship between the N nutrition of spruce and *Calluna*, but that no such relationship exists between *Calluna* and pine. These facts are undoubtedly connected with the rooting habits of the three species. Significant differences were found in the nutrient status of *Calluna* communities on different sites. The possibility of using *Calluna* as an indicator of site fertility is suggested.

LEYTON, L. 253

1951 Nutrient uptake of conifers. Rep. For. Comm. Lond. 1949-50: 118-119. fa

Work was continued on the nutrient status of Sitka spruce, Scots pine, and Corsican pine, growing in heathland sites in the presence, and in the absence, of *Calluna*. The effect of pH on the growth of

Sitka spruce seedlings was investigated in water cultures. In one series N was supplied as NH_4, in the other as NO_3, each series being otherwise identical in supply of nutrients. Maximum growth was obtained between pH 4 and pH 5, the NO_3 seedlings showing slightly better growth than the NH_4 seedlings. At extreme pH values (3 and 7) growth was markedly reduced, with pronounced abnormalities in root growth developing in the most acid solutions.

LEYTON, L. 254

1952 a The effect of pH and form of nitrogen on the growth of Sitka spruce seedlings. Forestry 25: 32-40. faA

The effect of pH and form of nitrogen (NH_4 and NO_3) on the growth of *Picea sitchensis* seedlings has been investigated in nutrient culture solutions over the range pH 3-7. In both N series the reaction for optimum growth of both shoot and root appears to lie between pH 4 and 5. Above and below this range there is a progressive fall in dry weight production accompanied by increasingly abnormal root development. The form of N supplied appeared to have little effect on total growth at equivalent reactions, but from the root/shoot ratios it seems that nitrate N stimulates a greater root production than does ammonia N.

LEYTON, L. 255

1952 b Mineral nutrient studies in heathland plantations. Rep. For. Res., Lond. 1950-1951: 127-129. a

Removal of heather from *Calluna*-dominated heathlands markedly increased K and N, and decreased Ca and Mn taken up by conifer needles, particularly of Sitka spruce. The P content of needles was increased by increasing amounts of P fertilizer up to 2 oz. per tree. Chlorosis and checking of spruce in presence of *Calluna* is probably due to severe competition for N. The marked positive correlation between the N status of spruce and *Calluna* plants found in the vicinity suggest that a luxuriant growth of the latter may be used as an indication of site fertility.

LEYTON, L. 256

1953 Growth and nutrition in heathland plantations. Rep. For. Comm. Lond. 1952: 117-119. a

The inhibitory effect of heather on the growth of Sitka spruce appears to be due to the limiting effect of the heather on the N

available for the spruce. Ground mineral phosphate appeared to stimulate the uptake of mineral N by Sitka spruce on screefed plots (i. e., plots from which heather had been removed). Phosphate increased the phosphate content of needles of Corsican pine and Scots pine and screefing increased the N contents.

LEYTON, L. 257

1954 The growth and mineral nutrition of spruce and pine in heathland plantations. Inst. Pap. For. Inst. Oxf. 31, 109 pp. A

Investigations on young plantations of Sitka spruce on heathland in Yorkshire, suggest that the growth of the trees is limited by nitrogen deficiency aggravated by the presence of the heather vegetation. Significant responses in height growth were obtained with nitrogen (as nitrochalk at 2 ozs. per plant) alone or combined with phosphate (as ground mineral phosphate at 2 ozs. per plant); no response was obtained with phosphate alone. Ground mineral phosphate applied at rates up to 6 ozs. per plant stimulated tree growth only when the heather had been removed by screefing, under which conditions, the nitrogen nutrition of the trees was also improved: the maximum response was obtained at approximately 2 ozs. per plant. The significant stimulation to growth following the application of a heather mulch was attributed in part at least, to the improved nitrogen nutrition of the trees as a result of the suppression of the heather vegetation. The growth of pines on these sites appeared to be less influenced by mineral deficiencies than that of the spruce.

LEYTON, L. 258

1955 a The influence of artificial shading of the ground vegetation on the nutrition and growth of Sitka Spruce (*Picea sitchensis*, Carr.) in a heathland plantation. Forestry 28: 1-6. A

Shading of the heather surrounding checked spruce in a 10 year old plantation by means of wooden laths resulted in a significant increase in height increment and mean weight per needle in the following year: this was accompanied by a significant increase in the nitrogen status of the trees. These findings offer a possible explanation for the improvement in the growth of spruce in mixture with nurse trees when the latter form a closed canopy and suppress the ground vegetation.

LEYTON, L. 259

1955 b The influence of heather mulching on the growth and nutrient status of Lawson Cypress. Forestry 28: 147-151 A

The application of a heather mulch to a heathland plantation of Lawson cypress, 7 and 11 years after establishment, has, at the end of 15 years, more than doubled the height growth of the trees compared with untreated controls. Analysis of the current foliage revealed considerably higher concentrations of nitrogen and phosphorus, suggesting that the response was at least partially due to an improved mineral nutrition.

LEYTON, L. AND K. A. ARMSON 260

1955 c Mineral composition of the foliage in relation to the growth of Scots pine. For. Sci. 1: 210-218. L

Significant linear correlations have been established between the height growth of Scots pine growing in even aged plantations on heathland, and the concentration of various nutrients in needles of different age sampled from various parts of the crown; in the case of needles from the terminal shoots, N, P, and K were all significantly related to growth.

The degree of differentiation between trees of different height, in terms of nutrient concentration in the current needles, was greatest in the terminal shoots and decreased progressively down the crown; with the exception of K, no differentiation was obtained with older needles. It is suggested that current needles from as near the terminal shoot as possible provide the best material for foliar analysis.

For all needle samples, tree height can be significantly related to needle composition by means of multiple regression equations.

It is tentatively suggested from these results that the growth of the pines is limited by deficiencies in N and K insofar as increased concentration of these nutrients in the needles, independent of the concentrations of other nutrients within the range encountered, are associated with increased height growth.

LEYTON, L. 261

1956 a Current investigations. Unpublished manuscripts. A

1) Effect of 3 levels of nitrogen (0, 2 and 4 ozs. ammonium

nitrate per plant) combined with 3 levels of potassium (0, 2 and 4 ozs. of potassium sulphate per plant) on the growth and nutrition of a 5 year old plantation of Japanese larch on heathland in Yorkshire. Assessments at the end of the year of application reveal significant increase in height growth with nitrogen, up to 2 ozs. level but no effect of potassium and no interaction.

2) Effect of 3 levels of nitrogen (0, 2, 4 ozs. of ammonium nitrate per plant) combined with 3 levels of phosphate (0, 2, 4 ozs. of ground mineral phosphate per plant) on the growth and nutrition of a 4 year old plantation of Japanese larch on moorland in South Wales. Assessments at end of the year of application reveal significant increase in height growth with nitrogen, up to the 2 ozs. level, but no effect of phosphate and no interaction.

3) Spraying 2–0 Sitka spruce seedlings in a heathland nursery in Yorkshire with urea (2 pints per plant of a solution containing 15 lbs. urea per 100 gallons water) on 4 occasions during the growing season resulted in a marked improvement in colour. Assessments at end of the year reveal no growth responses as yet.

LEYTON, L. 262

1956b The relationship between the growth and mineral composition of the foliage of Japanese larch (*Larix leptolepis*, Murr.) Plant and Soil 7: 167-177. L

Investigations on young Japanese trees growing on a heterogeneous site, have revealed significant linear correlations between the height of the trees and concentrations of N, P, K, and ash in the needles, but only doubtfully so in the case of Ca. Analysis of the multiple regression of height on the concentration of these nutrients suggests that only the contributions made by N and K are significant and a regression equation relating height to the concentration of these two nutrients in the needles has been calculated. It is argued from these results that, under the conditions of the experiment and the range of concentrations encountered, the height growth of the trees is limited by deficiencies in both N and K.

LIDL, O. 263

1948 Erfahrungen mit Kalkdüngungsversuchen im bayerischen Voralpengebiet Der Wald braucht Kalk (Experience with lime fertilization experiments in the lower mountain areas in Bavaria—The forest needs lime).

LIENARD, U. G. 264

1950 Communication sur la culture du peuplier (Communication on the cultivation of poplars). Agriculture, Louvain 48: 198-230.

LIMSTROM, G. A. 265

1948 Extent, character, and reforestation possibilities of land stripped for coal in the central states. Tech. Pap. cent. St. For. Exp. Sta. 109. 79 pp.

LOEW, O. AND S. HONDA 266

1904 (The influence of manganese on forest trees). Bull. Coll. Agric. Tokyo 6: 125-136. (Japanese)

LOHWASSER, W. 267

1953 Kalkdüngungsversuche im Eggegebirge und Hunsrück. Ertragskundliche Untersuchungen (Liming experiments in the Eggegebirge and Hunsrück: increment studies). Forstarchiv 24: 213-222. fa

Summarizes the results of a number of liming experiments dating from 1927 onwards, on moderately to slightly podzolized, base -deficient brown earths in these two regions, where thick raw humus layers had formed after two or more generations of pure Norway spruce; discusses the effects of liming on the soil, ground vegetation, regeneration, and increment as shown by studies made in 1950. Conclusions are as follows: (1) Liming has transformed densely compacted raw humus into a black, loose and more amorphous mass, the change proceeding quicker with larger dosages and where the lime was intimately mixed in with the humus. The CaO requirement for proper decomposition is 500-800 kg./ha. per cm. depth of humus layer. Liming considerably raised the pH of the humus and bleached horizons; at 600 kg./ha. it had also raised the pH of the B horizon after 20 years. It did not affect the depth of the humus, but reduced its sp. gr. (2) The ground flora became richer in species, nitrophilous species being characteristic invader, but the full effect depended on some opening of the canopy; limed plots also showed an increase of fungus sporophores and changes in the fungus flora. (3) After liming, natural regeneration of spruce is possible once more. It is noted, however, that in spite of improved nutrition and vigor, the seedling root mainly in the decomposed humus and may suffer in severe drought if canopy is removed too quickly. Planted spruce on limed plots did not go into check, closed

canopy earlier and grew more uniformly than the controls, but increased root competition will retard height growth after closure unless the spacing is wide enough and tending begins early. (4) In one trial, various fertilizers were applied at planting time to spruce on (a) unlimed plots, and (b) plots limed 1-3 years previously. On (a) 'Nitrophoska' (rate unspecified) checked growth, but on (b) growth was better than that of controls. Best growth was noted for (b) with 10 g. $(NH_4)_2SO_4$ + 50 g. basic slag and 37.5 g. 40% KCl per planting hole. (5) For spruce and beech the added increment due to liming averaged 1. 6 cu m. ha./year; of the 13 stands examined, 8 showed an extra 1-4 cu. m. and 3 up to 1 cu. m., while the remaining two showed zero or negative effects. The increase in stand increment was greatest where density was reduced by thinning to 0.6-0.7 of full yield-table stocking, and it should be born in mind that the increased foliage production after liming means earlier closure of canopy. (6) The rates of liming varied from 2000 to 10,000 kg. CaO/ha. (as quicklime, 80-95%, or as various "industrial" limes, Ca. 45% CaO). In general, 4000-10,000 kg. CaO/ha. should suffice. There was no difference in effect, however, between equal weights/ha. of quick lime and "industrial" limes, probably because the latter contain small amounts of other nutrients (e.g. N, P_2O_5 or trace elements), so that direct comparison of effects is difficult. (7) In the Hunsrück, liming makes it possible to grow beech directly after several generations of spruce, and in mixtures the beech will suppress the spruce unless the latter is grown in groups. Improved nutrition renders the beech more shade-bearing; natural pruning is slower, branching coarser; and wolf trees more frequent on the limed plots. (8) The effect of liming on increment shows no marked lapse even after 20 years. Even if the benefit to the soil is left out of account, costs (DM 150-250/ha.) are small in proportion to the effect, and should be covered by the added increment of the first 3-4 years. It should be advantageous to lime old stands 5-10 years before replanting, so as to reap the benefit of extra increment both on the old crop and on the new. (9) On many sites, liming should enable pure crops of conifers to be retained without fear of further soil degradation.

LUDBROOK, W. V. 268

1940 Boron deficiency symptoms on pine seedlings in water culture. J. Coun. sci. industr. Res. Aust. 13: 186-190. fa

In water cultures of young *Pinus radiata* and *P. taeda* most of the

plants given inadequate supplies of boron showed a reduced growth rate followed by cessation of apical growth and the development of necrotic symptoms at the growing points of the tips and roots. The cessation of apical growth was accompanied by swelling of the stem apex, death of young needles adjacent to the apical bud, and resin exudation from the bud. The juvenile needles were shortened and bluish green, while the mature needles were slow in appearing, few, and short. In some of the boron-deficient plants the fasciculate needles showed a tendency to fusion. It is not claimed that the needle fusion symptoms occurring in pine plantations are due to boron deficiency, as it is possible that needle fusion has more than one cause. Mycorrhizal development, which is dependent upon active root growth, may possibly be affected by boron deficiency in plantation soils.

LUDBROOK, W. V. 269

1942 a The effects of various concentrations of boron on the growth of pine seedlings in water culture. J. Aust. Inst. agric. Sci. 8: 112-114. fa

Growth rate of *Pinus radiata* increased with the concentration of boron in the nutrient solution up to 0.05 ppm. of added boron. Seedlings in solutions containing from 0.005 to 0.01 ppm. of added boron showed deficiency symptoms of degrees varying with the concentration. Toxicity symptoms were shown with 10 or more ppm. of added boron but not with 5 ppm. or less. Needles from boron deficient plants contained less starch than those receiving adequate boron but showed no difference in chlorophyll content.

LUDBROOK, W. V. 270

1942 b Fertilizer trials in southern New South Wales pine plantations. J. Coun. sci. indust. Res. Aust. 15: 307-314. Ba

Pinus caribaea and *P. taeda* affected by fused-needle disease did not respond to soil treatment with phosphatic fertilizers during the first season after treatment, but the percentage recovery from needle fusion became much higher in treated than in untreated trees during the subsequent 3 seasons. Treatment with boron compounds produced a much quicker response than superphosphate, for many of the treated plots produced new growth free of fused needles, the first season after treatment. This effect usually lasted only one season, however, and boron treatments subsequently

proved useless or detrimental. Application of 250 lbs. superphosphate per acre resulted in 19.9% increase in tree volume of *P. caribaea* by the third year after treatment, as compared with 13.7% increase on non-fertilized trees; 250 lbs. per acre brought 18.1% increase with *P. taeda* compared with 9.4% for non-fertilized trees. The increase was nearly enough to repay the cost of fertilizing. These results occurred at Woodburn when annual rainfall averaged only 27.2 inches for 2 years instead of the normal 47.5 inches. At Moss Vale, 150-300 lbs. superphosphate per acre had little effect on *P. radiata* 7, 9 or 17 years old, during 3 seasons after application. On 1-year-old volunteer seedlings the same rates of fertilization produced 35% increase in height in the first year. The 2nd year the increase was maintained with 300 lbs. application but not with 150 lbs.

LUKKALA, O. J. 271

1951 (Experiences from Jaakkoinsuo experimental drainage area). Commun. Inst. for. Finl. 39: 1-53. (Finnish) a

Jaakkoinsuo swamp, in Central Finland, was selected as an experimental area for forest drainage in 1908. The compression of the peat layer in 35 years after drainage varied between 21 and 41 cm. (9-34%). Vegetation maps, made in 1911, 1934, and 1948, show the striking effect of drainage on the ground vegetation. Ground water measurements, conducted from 1931 to 1941, show a regular annual fluctuation of the ground water table. Development of tree stands is followed and demonstrated in numerous permanent sample plots. On better swamp types, initially open or poorly stocked, the annual increment of growing stock is now 5-9 cu. m. per hectare, increasing continuously since the date of ditching. On poor types, however, the effect of drainage on tree growth has been much slighter. On drained swamps, as a whole, natural reproduction has been good and afforestation has succeeded. Since intensified drainage was not able to eradicate Sphagnum on poor-moors, various other methods to accomplish this end were tested. Sand, spread on the swamp surface in a thick layer, destroyed Sphagnum at least temporarily, but the effect on tree growth was hardly discernible. Ground limestone, when applied 6 tons per hectare, destroyed Sphagnum completely but affected tree growth surprisingly little. Excellent results were achieved by applying 5 to 10 tons of wood ash per hectare, particularly on Sphagnum bogs poor in nutrients. Commercial K and P fertilizers also improved tree growth on drain-

ed swamps, this effect, however, not being comparable to that of wood ash.

LUKKALA, O. J. 272

1955 (Soil improving substances and fertilizers as an aid to forest drainage). Metsät. Aikakausl. 8: 189-191, 273-276. (Finnish w/English summary) fa

Review experiments made by the Forest Research Institute to improve forest growth where drainage alone is not effective. Results indicate that a layer of sand, 5 cm. thick (500 cu. meter/ha), or of clay, considerably increases forest growth. A lime layer, e.g. crushed limestone at about 4000 kg. per ha., retards the growth of, and sometimes kills sphagnum on acid swamps (pH lower than 4) but hardly affects tree growth. Wood ash at about 3000-4000 kg. per ha. converts most drained swamps that have stayed treeless into excellent woodland. Preliminary experiments with fertilizers indicate that K and P fertilizers, e.g. 200 kg/ha., potassium oxide (K^2O, 50%) and 500 kg. per ha. fine phosphate (P_2O_5, 30%), cause a considerable increase in forest growth on swamps with poor nutritive properties.

LUNT, H. A. 273

1938 The use of fertilizer in the coniferous nursery with special reference to *Pinus resinosa*. Bull. Conn. agric. Exp. Sta. 416: 722-766. A

This bulletin presents the data from a number of nursery fertilization experiments in seedbeds, transplant beds, and in soil frames. It includes a discussion on the requirements of nursery stock based upon the amount of nitrogen, phosphorus, potassium, calcium, and dry matter in the plants. It was concluded that, in general, red pine and other conifers respond to fertilization but care is needed to avoid injury from overdosages. It was not possible, under the conditions of the tests, to shorten the period of time necessary for plants to remain in the nursery, but the treatments resulted in the production of somewhat larger plants.

LUNT, H. A. 274

1942 A pot culture experiment with undisturbed forest soil. Proc. Soil Sci. Soc. Amer. 6: 403. A

Blocks of the upper 6 inches of soil, together with the over-lying A_0 were excavated and transferred to 2-gallon pots and to wooden squares 12 × 12 × 6 in., and brought to the greenhouse. Treatments were applied and Norway spruce seeded. At intervals the soil in the pots was flooded with water, then the water removed by suction and analyzed. In the first test, the soils were kept inside in winter, and treatments consisted of fertilizers and/or lime. In the second, the soils were kept outside the year around, and treatments consisted of burning, raking, and mixing of the A_0. The high mortality of seedlings from damping off was much reduced where the duff was removed, burned, or turned under. Phosphorus, either alone or with nitrogen, favored growth. The method has considerable merit for studying the effect of certain treatments upon forest soil.

LUNT, H. A. 275

1946 Effect of fertilizer treatment on field planted spruce. Proc. Soil Sci. Soc. Amer. 10: 406-409. A

Counts and measurements were made on several lots of white spruce and Norway spruce (a) fertilized in the nursery transplant bed but not in the field, and (b) fertilized only when planted in the field. In the first instance there were no consistent or significant effects on survival. In the second, survival was poorer where 6-10-4 fertilizer was applied in the planting hole. Neither starter solution nor vitamin B_1 had any effect on survival. There was some indication that growth was favored by starter solution.

LUNT, H. A. 276

1947 The response of hybrid poplar and other forest tree species to fertilizer and lime treatment in concrete soil frames. J. agric. Res. 74: 113-132. A

A set of 48 concrete-walled frames, each 1/10000 acre in size, and containing Cheshire loam was used to determine the growth response of red pine, southern red oak, sugar maple, Norway spruce, white ash, and white spruce seedlings, and single clone hybrid poplar cuttings, to lime and fertilizer treatments. The pine, spruces, and red oak were adversely affected by lime, but sugar maple and white ash were benefitted by it. Red pine and Norway spruce showed least response to nitrogen and phosphorus. Potassium response was negative in most cases. Hybrid poplar responses to nitrogen and to lime were highly significant.

1950 Wood ashes as a fertilizer. Wood products for fertilizer. Bull. Northeast. Wood Util. Coun. 32: 11-14. fa

Discusses the value and use of wood ashes as K, N, and P fertilizers.

1951 a Liming and twenty years of litter raking and burning under red (and white) pine. Proc. Soil Sci. Soc. Amer. 15: 381-390. aA

On a series of six 1/40th acre plots in a 27-year-old red pine plantation on Merrimac loamy sand, the annual litter removal by raking was compared over a period of 19 years with annual litter burning and with undisturbed litter, with and without liming. A similar series under white pine was destroyed by the 1938 hurricane after 9 years of treatment. On a seventh red pine plot the natural forest floor was supplemented with litter from the two red pine raked plots.

The initial forest floor under red pine averaged 27800 (S.D.m. 5972) lbs./acre and the annual needle fall 3555 lbs. Final measurements indicated a yearly gain of 212 to 258 lbs. for the normal undisturbed plots and an annual decomposition rate of about 3300 lbs./acre. Comparable figures for the triple Ao plot are 1722 lbs. annual accumulation and 7927 lbs. annually decomposed. White pine forest floor averaged 21539 (S.D.m. 6511) lbs./acre and annual needle fall was 21% higher than red pine.

Treatments caused relatively small differences in d.b.h. and total height, with somewhat better defined differences in tree volume. Raking had a slightly unfavorable effect on growth, due, probably, to lower soil moisture and the lower content of available P and Ca, and the almost complete removal of the surface supply of plant nutrients. Burning favored both height growth (8.1% more than the check in relation to original heights) and volume growth (18.8 % more than check) as the result, probably, of the higher values in the top soil for pH, total N, and available P and Ca, and possibly other unknown benefits. Best growth was obtained on the triple Ao plot (22.3% more height and 49.8% more volume than the check) due chiefly to the greatly augmented supply of plant nutrients released by the estimated 8000 lbs. of litter decomposed annually. Liming increased growth 10 to 29% over the comparable unlimed

plots and was associated with higher soil moisture content and a slightly higher level of N, available P and base capacity, and a much higher exchangeable Ca content.

Although burning favored growth, it is believed that if continued for a long time it would ultimately have an adverse effect.

LUNT, H. A. 279

1951 b Wood chips as a soil amendment. Chipped wood production and uses. Bull. Northeast. Wood Util. Coun. 33: 83-89. faA

Gives preliminary results of the studies in progress: (1) none of the wood chips used increased the acidity of the soil; (2) first crop yields following the application of chips were markedly reduced as a results of N starvation; (3) aspen-grey birch chips decomposed the most rapidly, and pine chips the least rapidly; (4) bulk density of the soil was reduced, and its water-holding capacity was increased in proportion to the rate of chip application.

LUNT, H. A. 280

1951 c Effect of slash mulch and slash burn on pine and spruce plantings. Bull. Conn. agric. Exp. Sta. 548. 21 pp. fa

The experiments were made on sandy soils. (1) Freshly cut 7 ft. trees from a *Pinus resinosa* plantation were laid between and under the remaining trees. (2) Green *P. strobus* slash, obtained from another part of the plantation, was spread between 4 ft. trees of the same species. (3) Dead *P. strobus* slash and (4) dead *P. sylvestris* slash, each used on the land on which it was produced, were added to certain plots and burned on other plots, prior to planting with *P. strobus* and *Picea abies*. Survival counts (on the new plantings), increment measurements, and soil studies, were made over a period of 3-6 years.

Survival of *P. strobus* and *Picea abies* was essentially unaffected by treatment, except in one case spruce survival was reduced by 20%. The effect of slash on increment appeared to be dependent on kind and source of slash, and species treated.

Experiment (1) was not beneficial; (2) increased growth by about 13% over a 6-year period; (3) produced 13% increase in growth in 5 years; (4) had no effect. The probable explanation is that P. *resinosa* is less exacting than either *P. strobus* or *Picea abies*;

that both *P. resinosa* and *P. sylvestris* slash, being lower in nutrient content compared with *P. strobus* and *Picea abies,* add fewer nutrients to the soil; and that slash produced on poor soil and on the same area is less effective than that grown on another area of more fertile soil. Burning the slash before planting, increased growth of *P. strobus* by 17-18% but had no effect on *Picea abies.* Soil tests indicated that available K and total soluble salt content were slightly higer under slash, and considerably higher where slash was burnt.

LUNT, H. A. 281

1954 Wood chips (and sawdust) as soil amendments. The use of wood chips in agriculture. Bull. Northeast. Wood Util. Coun. 41: 33-48. L

Studies on the effect of woodchips and sawdust as soil amendments were conducted in the greenhouse, in outdoor soil frames and in the field. It is concluded that direct application of fresh chips to the soil without supplemental nitrogen may or may not prove beneficial, depending on the soil, the crop, the season, and other factors. A safer practice is to always include sufficient N to narrow the C/N ratio appreciably. Also, there should be an interval of about a year between applications and planting or seeding. Probable better usage of woodchips or sawdust is (1) as bedding in the barn, followed by field application of the manure or (2) after adequately composting with other organic materials.

LUNT, H. A. 282

1955 The use of wood chips and other wood fragments as soil amendments. Bull. Conn. agric. Exp. Sta. 593. 46 pp. L

Studies were conducted over a 5 year period to determine the effectiveness of woodchips (and sawdust) for soil improvement. In most cases the chips were applied only once and worked into the soil, with and without extra nitrogen. Crop yields or plant growth was measured and various tests made on the soils. The work was done in greenhouse pots, in outdoor soil frames, and on field plots.

These studies show that woodchips (or sawdust): (1) had no appreciable effect on soil acidity nor were they toxic to plants aside from a temporary N deficiency. (2) Chips had a modest but generally favorable effect on soil structure, organic matter content, and associated soil properties. (3) When fresh, chips almost invari-

ably reduced first crop growth, and were not consistant in their effect on succeeding crops. (4) When supplemented with sufficient nitrogen or when composted before applying, chips did not decrease first crop yields, and they generally increased yields of succeeding crops. (5) Chips are probably more effective on sandy soils than on loams, although very coarse textured soils may become excessively loose and open the first year or two, unless the chips are first composted. (6) Birch chips decomposed more rapidly than either oak or pine and would require the most N to prevent deficiencies. Pine decomposition was slowest of the three and required the least N. In general, pine chips were more effective than oak or birch in improving the soil.

Lutz, H. J. 283

1943 Utilization of nitrogen in forestry. Proc. nat. Comm. Nitrog. Util. 2: 36-40. a

Consideration is given present and future utilization of nitrogen fertilizers in forestry, as follows: (1) in forest tree nurseries, (2) in the artificial establishment of forest planations, (3) in the natural establishment of tree reproduction, and (4) in favoring the growth of forest stands, either artificially or naturally established.

Lutz, H. J. and R. F. Chandler, Jr. 284

1947 Forest soils. xi + 514 pp. John Wiley, New York

Lynch, D. W., W. C. Davis, L. R. Roof, and C. F. Korstian 285

1943 Influence of nursery fungicide-fertilizer treatments on survival and growth in a southern pine plantation. J. For. 41: 411-413. fa

The treatments included ferrous sulphate and phosphoric acid applied in solution separately or in combination at the rate of a fraction of an ounce per sq. ft. of nursery seedbed following sowing. The present paper describes an experiment to test the hold over effects of the treatments in a forest plantation of loblolly, shortleaf and slash pines. Measurements of height growth and survival at the end of the first and second years after planting showed that: (a) Height growth of loblolly pine was not affected by the chemicals, while relatively high mortality of seedlings of this species was associated with all treatments containing phosphoric acid. (b)

All treatments increased the height growth of shortleaf pine seedlings during the first but not during the second year after planting; mortality in this species was relatively high for the two most concentrated treatments irrespective of the chemical. (c) Untreated seedlings of slash pine were distinctly taller than treated seedlings in both the first and second years after planting; mortality for this species was high throughout and it was not possible to detect any significant effects due to the treatments.

MACDONALD, J. A. B. 286

1950 Afforestation of peat. Rep. For. Res., Lond. 1948-1949: 43-47. fa

Summarizes the findings of a complete survey of each of the Commission's 330 peatland experiments, which will form the basis of a bulletin on the planting of peatlands to be published shortly.

MACDONALD, W. A. AND S. DUNN 287

1953 Sawdust composts in soil improvement. II. Pot culture studies with compost mixtures of sawdust and manure, steam treated composts, and miscellaneous mixtures. Plant and Soil 4: 235-247. L

Mixtures of sawdust with hen manure and/or green vegetation (silage) produced significantly greater yields in greenhouse pot cultures after one year of composting instead of 5 months, especially the mixture of sawdust-manure-silage in equal parts as well as the mixture of 3 parts sawdust to 1 of manure.

Sawdust-hen manure mixtures, in which the sawdust was first treated with high-pressure steam, after standing for almost 2 months produced better growth in greenhouse pot cultures than the soil control.

Pot cultures of plants grown in sawdust-soil mixtures (both rotted and fresh sawdust) of varying proportions gave inconclusive yield data. Apparently other factors such as variations in water supply (if this is not known or accurately controlled) may affect plant growth to a greater extent.

MAISENFELDER, L. C. 288

1946 Fertilizer stimulates height growth of cottonwoods. Farm Victory 24: 7-8.

MAKI, T. E. AND H. MARSHALL 289

1954 Effect of soaking with indolebutyric acid on root development and survival of tree seedlings. Bot. Gaz. 107: 268-276. A

One-year-old seedlings of loblolly pine (*Pinus taeda L.*) and eastern red oak (*Quercus borealis maxima*) were treated immediately before planting by soaking the roots for 24 hours (in addition to a 6-hour series for loblolly pine) in aqueous solutions in indolebutyric acid ranging in concentration from 2.5 to 160 mg. per liter. Root volumes were measured by displacement before planting and again when seedlings were lifted at the end of the first growing season.

Consistant increases in root volume of red oak occurred in all concentrations of indolebutyric acid, and these increases were statistically significant for all concentrations of 40 mg. per liter or more.

Survival of red oak seedlings treated with indolebutyric acid at 5 mg./l. was slightly better than that of controls; on the other hand, a highly significant drop in survival occurred at concentrations of 80 mg./l. and higher.

Indolebutyric acid generally increased the root volume of loblolly pine, but the relationship of root volume to acid concentration was not consistant. Moreover, concentrations higher than 20 mg./l. cause a marked increase in mortality of pine.

MAKI, T. E. AND B. W. HENRY 290

1951 Root rot control and soil improvement at the Ashe forest nursery. Occ. Pap. Sth. For. Exp. Sta. 119, 23 pp. A

During a three-year study (1946-1948) approximately 110 standard nursery beds (4 ft. × 400 ft.) were sown to longleaf, slash, and loblolly pines in various tests on root rot and soil management at the Ashe Forest Nursery near Brooklyn, Mississippi. Over 200,000 seedlings were individually examined and handled in the laboratory and field, and over 100,000 seedlings were planted in experimental plots for observations on survival and growth.

Ethylene dibromide in a 20 per cent (by volume) solution at the rate of 30 to 32 gallons per acre gave excellent control of root rot. Fall sowing of longleaf pine also controlled root rot adequately (other southern pines are normally sown in the spring), and sawdust at the rate of 135 cubic yards per acre (approximately a 1-

inch deep layer) reduced the incidence of rot very materially.

The soils were found to be particularly deficient in organic matter and nitrogen. Addition of sawdust, ammonium nitrate at the rates of 300 to 600 lb., 20 per cent superphosphate at the rate of 3,000 pounds, and 50 per cent muriate of potash at the rate of 240 pounds per acre were deemed necessary for sustaining production of seedlings of satisfactory size and vigor. Nitrogen alone did not improve survival, but coupled with superphosphate, potash, or both, it clearly brought about improvement both in seedling size and in vigor.

MAKI, T. E. 291

1953 Some aspects of inorganic fertilizer applications in forest nurseries, Proc. Ass. Sth. agric. Wkrs. 1953: 207.

MAKI, T. E. 292

1955 Effect of fertilizers on the growth of loblolly pine plantations. Unpublished manuscript, N. C. St. Coll., Raleigh. A

Fertilizers were applied in March of three consecutive years (1951, '52, and '53) to loblolly pine plantations in Durham County, North Carolina. Four separate plantations were used in the experiment, the ages of the plantings being six, nine, twelve, and sixteen years at the time the first fertilizer application was made. This report covers preliminary results based on three-year growth measurements of the three oldest plantations; the youngest plantation was excluded because the trees were too small to obtain a uniform measure of breast-high (4½ feet above general ground level) diameter growth.

The sixteen and twelve-year plantations were situated on Georgeville silt loam and the nine-year plantation on Alamance silt loam. The fertilizer combinations of nitrogen, phosphate and potassium were at rates per acre of 0, 80 and 160 lb. N, and 0, 40 and 80 lb. P_2O_5 and of K_2O.

There was a total of 13 treatment combinations on each of the 16 and 12-year old plantations, but only 11 in the 9-year old plantation. For the sake of simplicity, results for only nine treatments are reported here, representing a 3×3 factorial in all three levels of nitrogen (i.e., 0, 80, and 160 lb. N per acre) and phosphate, (0, 40, and 80 lb. P_2O_5 per acre), all at the unit level (40 lb. per acre) of K_2O.

Three-year diameter growth was significantly better for trees fertilized with nitrogen than for those receiving no nitrogen. The average increase was about 0.2 inches for the first 80 lb. of N all three plantations. Only in the 12-year plantation was there a sufficient additional (0.15 inches) reponse to the second 80 lbs. of N to exceed its standard error.

Response to phosphate fertilizing was entirely negligible, but there was a suggestion, not yet statistically significant, that a response to potassium is developing.

Average height growth varied slightly, and although there was a trend toward increased growth in relation to nitrogen level, the results were too variable to warrant detailed statistical analysis at this time. On the average, the trees were growing at the rate of about 2 to 2½ feet per year, a quite satisfactory rate for the sites in question.

It can only be speculated at this stage whether fertilizing will prove to be an economic practice in loblolly pine stands. There may be residual effects, not yet manifest, that are of long range significance, but these effects, if they should develop, need confirmation through later measurements and observations.

MAKI, T. E. 293

1955 Stimulating seed production by fertilization and girdling. Proc. 3rd sth. Conf. For. Tree Improve. 1955: 74-80.

MALMSTRÖM, C. 294

1935 Om näringsförhållandenas betydelse för torvmarkers skogsproduktiva förmåga (On the importance of the nutritional relations on forest production capacity of peat soils). Medd. SkogsforsknInst. Stockh. 28 (6): 571-650. (Swedish w/German summary)

MALMSTRÖM, C. 295

1943 Skogliga gödslingsförsök pa dikade svaga torvmarker (Forestry trials with fertilizers on poorly drained peat lands). Norrlands SkogsvFörb. Tidskr. 4: 273-292. (Swedish) fa

The history of Alund's trials of wood ash as a fertilizer for drained sphagnum bogs in Västerbotten is briefly recapitulated. Following applications of wood ash at rates of respectively 3.3 and 12.5 metric tons per ha., plots on the Södra and Norra Hallmyrar,—almost treeless bogs,—first showed improvements in the ground

flora and later developed thrifty young stands of spontaneous birch with some Scots pine and Norway spruce admixed. An inspection in 1943 showed that the development of young stands on these plots was highly satisfactory, with no sign of any relapse in growth, although no further applications of wood ash had been made over periods of 25 years in one case and 17 years in the other. The unfertilized areas were still practically as poor as ever.

Brief notes are also included on similar trials on other bogs, where the same initial improvements have been noted, though it is as yet too early for any conclusions regarding the future of the trees that are now colonizing the fertilized areas. Among such trials, those on the Flakatjälsmyr in Kulbäcksliden are specially mentioned. Here plots on drained and undrained areas, fertilized in 1939 with wood ash, show improvements in ground vegetation and stocking by spontaneous tree seedlings on both types of site. In 1941 more extensive trials were begun by L.-G. Romell, using a basic chemical fertilizer mixture, with or without phosphate and various trace elements. So far the complete fertilizer has given the best results, followed by the basic mixture plus phosphate. As treatments with soda lye, sodium chlorate or nitrogenous fertilizer have shown no sign of comparable effects, it is inferred that the favorable reaction of wood ash or chemical mixtures is due to direct fertilizing and does not depend on general base relationship, poisoning out of sphagnum, or hastening of peat decomposition. Phosphorus is indicated as one of the most important needs.

The long duration of the effects of wood ash in Alund's trials is believed to be due to retention of nutrients by the peat colloids. How long such effects may last is unknown, but clearly some further fertilizing will eventually be necessary, as it will in the case of many drained bogs, which were at first sufficiently rich in nutrients to grow forest without fertilizing.

The chief difficulty in the fertilizing of bogland would be to procure the wood ash or other suitable fertilizer. Transport and spreading are easiest when the bogs are frozen and slightly snow-covered.

MALMSTROM, C. 296

1949 Studier över skogstyper och trädslagsfördelning inom Västerbottens län (Studies on the forest types of and the distribution of tree species in the county of Västerbotten). Medd. SkogsforsknInst. Stockh. 37(11): 231 pp. (Swedish w/German summary)

MALMSTROM, C. 297

1950 Om torvmarkers nyttiggörande för skogsproduction (On utilization of peat soils for forest growth). Norrlands SkogsvFörb. Tidskr. 1950 (1): 15-26. (Swedish) fa

Discusses the effect of the thickness of the peat layer, of the chemistry of the site and of the soil carried down by streams draining into the area, on the suitability of peat sites for drainage for afforestation, with or without the addition of fertilizers. Gives rough figures showing the areas in Sweden already drained and those undrained but suitable for drainage. Discusses draining techniques using hand labor, mechanical means or explosives.

MALMSTROM, C. 298

1952 Svenska gödslingsförsök för belysande av de näringsekologiska villkoren för skogsväxt på torvmark (Swedish fertilizing experiments elucidating the nutrient-ecological conditions of forest growth on peat soils). Commun. Inst. for. Finl. 40: 1-27. (Swedish) a

Orientative experiments indicated that shortage of mineral nutrients can be reason for failure of forest growth on drained swamps. The results of systematic experiments are concentrated in the following statements: On deep swamps (peat layer over 40 cm. thick) the forest production after drainage is dependent on nutrients present in the peat. In some instances this source is satisfactory for prolonged production. But more often it is sufficient for a short time only. On shallow swamps (peat layer less than 40 cm.) the production does not depend on the nutrient content of peat layer only but also on the mineral soil beneath it. Therefore forest growth can be continuous. Sometimes the peat is so poor in nutrients that mineral fertilizers are required to get tree growth started.

MARAN, B. 299

1949 (Nutrition of forest trees on the rendzinas of the Karlstejn area). Apr. vyzkum. Ust. lesn. CSR 3: 75-107. (Russian) fa

Presents the tabulated results of analyses of foliage, wood and bark of *Fraxinus excelsior*, *Populus tremula*, *Acer platanoides*, *Tilia cordata*, *Cornus mas*, *Carpinus betulus*, *Sorbus torminalis*, *Betula verrucosa*, *Quercus pubescens* and *Picea abies*, at various levels be-

tween root collar and top, for trees growing on rendzinas of the Karlštejn area. In the foliage, the mineral content was found to be greater than on carbonate-free soils and, in general, greater than that listed in literature. The highest proportion of mineral nutrients was found in the foliage of *F. excelsior*, and the lowest, in *B. verrucosa*. The proportion of Ca in the foliage decreases as the proportion of acids increases. The content of mineral nutrients in the wood was found to be much less than in foliage, the respective ratios varying between ¼ and 1/14. In young wood (tops) the mineral content is 10-30% higher than in old wood, and rises the higher the thinner the stem. The greatest differences are observed for Ca and K. The wood of lime contains the largest proportion of ash, pine the smallest. The mineral content of bark was found to be much greater than on carbonate-free soils and than that usually given in literature. Young bark contains more mineral than old, and old bark more than dead bark. The bark of hornbeam has the highest ash content, that of pine the lowest.

MARAN, B. 300

1954 (Soil preparation before afforestation). Za social. Zeměd. 4: 584-592. (Czech)

MARCET, E. 301

1954 Une procédé pour mieux réussir les semis de tremble (A method of raising aspen seedlings). Schweiz. Z. Forstw. 105: 614-616. Ba

Aspen seeds are sown 1½-2 cm. apart in shallow pans on damp thin sheets of pressed peat lying on a layer of "terralite" (a mica product) over a layer of moist gravel. The pans are kept in a light and fairly warm place, watered as needed, and supplied with fertilizer. After 6-8 weeks the 10-15 cm. seedlings, whose roots will have penetrated the peat and spread out in the terralite, can be planted out of doors. Such plants have reached heights of 1 m. or more in the first season.

MARTH, R. C. AND F. E. GARDNER 302

1941 Responses of coniferous evergreens to fertilizer applications. Proc. Amer. Soc. hort. Sci. 38: 709-714. fa

A four year study of the effect of fertilizing nursery stock of horticultural varieties of *Thuja occidentalis* and *Juniperus communis* showed that under conditions of the experiment (1) N fertilizers

at suitable rates (not to exceed 200 lbs. per acre) give increased growth; (2) NPK was better than N alone or N in combination with P or K separately; (3) with continuous use, nitrate of soda and urea were better sources of N than sulphate of ammonia; and (4) a NPK fertilizer approximating a 2-9-14 standard grade commercial fertilizer, applied in spring or late summer at 1,400 lbs. per acre, gave consistantly satisfactory results with both species.

MARX, 303

1947 Holzasche, ein Kaliphosphatdünger (Wood ash as a potassium phosphate fertilizer). Dtsch. Landw., Berl. 1: 87-88. fa

Discusses the use of wood ash to increase the content of K and P_2O_5 in the soil and includes a table showing the % K_2O, P_2O_5, and CaO in ash from birch, beech, oak, pine, larch, lime, spruce, and elm, from unspecified coniferous and deciduous woods, and from some agricultural residues. Values range from 2.5 to 37.84% (lime) for K_2O, from 0.95 to 8.65% (beech) for P_2O_5 and from 20.3 to 75.46% (oak) for CaO. The lowest value in each case is for an unspecified coniferous ash.

MATTOON, W. R. 304

1929 Shortleaf and loblolly pine litter and humus a valuable fertilizer. For. Wrkr. U. S. 5: 14-15.

MAYER-KRAPOLL, H. 305

1956 a Die Anwendung von Handelsdüngemitteln insbesondere von Stickstoff in der Forstwirtschaft (The use of commercial fertilizers particularly nitrogen in forestry). 126 pp., Ruhr-Stickstoff, Bochum.* Van

Summarizes the research in forestry with fertilizers by early and recent investigators. The results of numerous studies are presented in tabular and graphical form. The importance of the effect of fertilizers on the quality of nursery stock, growth of forest stands and plantations and on the amelioration of degraded forest soils is stressed. Special sections are devoted to the use of fertilizers with heath land and coast afforestation and for increased forage production on game management areas. Of interest are the fertilizing schedules for various purposes.

The raw humus problem receives considerable attention. When raw humus is allowed to accumulate the biogenic nutrient cycle is interrupted, soil degradation sets in, resulting in growth stagnation.

Raw humus seems to impede natural regeneration because of its limited capacity to absorb moisture from precipitation. Amelioration measures are therefore of great importance to water conservation aside from the fact that in most cases silvicultural measures effected on degraded soils are only successful if such soils have been previously restored to health. The lack of free available nitrogen prevents the rapid transformation of raw humus into true humus forms. Liming would shift the pH of the raw humus to the neutral side, thereby stimulating micro-biological activity with subsequent creation of mild humus. Liming alone is not sufficient, however, but must be accompanied by a nitrogen application.

While the results of liming may not be expected for several years, the author recommends the use of ammonia gas to bring about spontaneous auto-oxidation of the lignin. Raw humus can be converted in a few days into a high-grade dark humus with ammonia gas. The CO_2 production as a result of nitrogen amelioration appears to be considerably less than when lime is applied. Ammonia gas may also be very effective in reclaiming moorland for agricultural and forestry use. Two machines for the application of ammonia gas are described.

*Translated and published by Nitrogen Division, Allied Chemical and Dye Corporation, New York.

MAYER-KRAPOLL, H. 306

1956 b Neue Möglichkeiten für Stickstoff in der Forstwirtschaft (New possibilities for nitrogen in forestry). Chem. Industr., Düsseldorf 8: 243-245. Van

The importance of nitrogen for the conversion of raw humus and subsequent growth improvement of pure coniferous stands is discussed. Application of large quantities of lime is effective. However, the nitrogen released as a result is fixed so that less nitrogen is available to the plants than previously. Liming must therefore be combined with an application of nitrogen. Cultivation of lupine in this respect is not practical because of its light requirement. The ordinary N fertilizers have not as rapid an effect as desirable. The salts are merely scattered on the surface and are not worked in so that the nitrogen is more or less fixed on the surface by intersusception into the lignin substances of the uppermost layers of the raw humus. By using NH_3 the wetting resistance of raw humus is reduced which aside from phytophysiological requirements is

also of importance for the activity of micro-organisms. In this way conditions are created for the commencement of the biozoonosis of the soil. Improvement of the water absorption of raw humus also facilitates natural reproduction. The greatest advantage of ammonia improvement is that due to the elimination of resistance to wetting, water-soluble ammonium humates are formed which can filter depth-wise so that tree species are stimulated to develop deeper root systems. The fact that such action is possible only with NH_3, is due not only to this form of nitrogen but in particular to the nature of the introduction of the nitrogen. Other values ascribed to NH_3 application are the increase of growth and seed production of the treated stands.

McComb, A. L. 307

1938 The relation between mycorrhizae and the development and nutrient absorption of pine seedlings in a prairie nursery. J. For. 36: 1148-1154. fa

In a nursery established on old agricultural land at Ames, Iowa, it was found *inter alia* that a large proportion of *Pinus virginiana* seedlings ceased growth almost entirely in the middle of the first growing season as a result of insufficient phosphorus nutrition in the absence of mycorrhizal association. Only seedlings with mycorrhiza present in their roots absorbed phosphorus at a sufficient rate and developed in a normal manner.

McComb, A. L. 308

1943 Mycorrhizae and phosphorous nutrition of pine seedlings in a prairie soil nursey. Bull. Ia. agric. Exp. Sta. 314: 582-612. A

At a new forest tree nursery established on O'Neil sandy loam soil pine seedlings failed to grow unless they developed mycorrhizae. Formation of mycorrhizae and satisfactory growth followed inoculation of the nursery soil with duff and humus from a healthy pine plantation.

Comparison of mycorrhizal and non-mycorrhizal Virginia pine seedlings revealed that plants with mycorrhizae had much larger root systems and more and larger absorbing root tips than plants without mycorrhizae. Infection with mycorrhizal fungi increased rather than retarded growth of short roots. Similarly, chemical analyses of the seedlings showed that mycorrhizal seedlings con-

tained four times as much phosphorus as non-mycorrhizal plants. On a percentage dry weight basis mycorrhizal plants absorbed twice as much phosphorus, and there was no difference in the absorption of nitrogen and potassium.

Fertilizer experiments using jack pine and other species of conifers on uninoculated soil showed that good growth followed phosphorus fertilization, while little or no response was obtained with nitrogen. Seedling growth following phosphorus fertilization was approximately equal to that obtained when unfertilized soil was inoculated with humus containing mycorrhizal material.

Short roots of fertilized white pine seedlings from uninoculated soil were mycorrhizae of the ectotrophic type and possessed a very compact mantle composed of fine mycelia. Short roots from seedlings on inoculated unfertilized soil were usually ectendotrophic mycorrhizae with coarse hyphal threads. Two species of fungi may be involved in the formation of mycorrhizae on white pine, one of which may have been subdominant in the original nursery soil and incapable of forming mycorrhizae without phosphorus fertilization. Because of a compact mantle and fine hyphae the mycorrhizal nature of many short roots could not be determined without sectioning.

Jack pine was found to be mycorrhizal and to make satisfactory growth when grown on two forest soils taken from oak-hickory stands. This species failed completely when grown in an alkaline prairie soil of the Webster series.

Factors possibly of importance in the phosphorus nutrition of pine are discussed. It is suggested that failure of non-mycorrhizal pines on O'Neil soil may be due to a low level of root respiration, and that root respiration and activity may be stimulated by secretions from mycorrhizal fungi and by phosphorus.

McComb, A. L. 309

1949 Some fertilizer experiments with deciduous forest tree seedlings on several Iowa soils. Res. Bull. Ia. agric. Exp. Sta. 369: 406-448. A

The results of box, nursery and field experiments are described. The growth of seedling green ash, American elm, red oak and black locust was studied in relation to nitrogen, phosphorus and potassium fertilization of four Iowa soils. Fertilizers were added to B and C horizon soil materials and growth compared with that obtained on unfertilized surface and sub-soils. The soils employed were the

gray-brown podzolic forest Lindley and prairie Clarion, Tama and O'Neill. Factors causing chlorosis on calcareous Clarion C horizon soil were also investigated.

Nitrogen was found deficient for growth of ash, elm and oak. Black locust, a legume, did not respond to nitrogen fertilization. As the residual soil nitrogen supply increased, growth response decreased in magnitude. On Tama C horizon soil with residual total nitrogen at 600 pounds per acre the response of American elm to added nitrogen was 600 percent, while on O'Neill soil containing 1900 pounds residual nitrogen responses were small or nil. The evidence suggests that about 2000 pounds total nitrogen per acre is a level above which seedling nitrogen responses could not be expected under average conditions.

Phosphorus was found to be consistently and significantly deficient on Lindley soil only. Seedling responses to phosphorus were smaller than to nitrogen. On O'Neill a marked root growth response occurred with red oak.

Potassium was not deficient on O'Neill or Clarion soils.

Severe chlorosis was associated with restricted growth of ash, oak and elm on calcareous Clarion C horizon soil. Inconclusive evidence pointed to unavailability of iron.

Several species differences were evident. Black locust responded only to phosphorus. Red oak showed marked root responses to phosphorus, was the only species with ectotrophic mycorrhizae, and was least tolerant of high soil pH. Green ash was most tolerant of alkaline soil.

A comparison of greenhouse and outdoor experiments using the same species and soil indicated that greenhouse experiments will not yield, necessarily, accurate information regarding order and degree of response to fertilizers applied in outdoor experiments or plantings.

A marked superiority in the growth of red oak and green ash on forest Lindley soil, as compared to prairie Clarion and Tama, was noted. Soil organic matter and mycorrhizal factors may explain the superiority of the forest soil.

Under average eroded-field conditions in Iowa, fertilizer responses of hardwood planting stock will probably be small or nil. Exceptions to this statement might be necessary for areas completely devoid of surface soil layers and bare of weeds or grasses. Phosphorus fertilization for black locust is indicated if quick and complete coverage of raw subsoil gullies is desired.

McComb, A. L. and J. E. Griffith 310

1946 Growth stimulation and phosphorus absorption of mycorrhizal and non-mycorrhizal northern white pine and douglas fir seedlings in relation to fertilizer treatment. Plant Physiol. 21: 11-17.

Two-year-old seedlings of northern white pine and Douglas fir made very satisfactory growth on O'Neill soil inoculated with coniferous humus containing mycorrhizal fungi. On uninoculated soil fertilized with phosphorus, white pine seedlings formed mycorrhizae and made satisfactory growth; but Douglas fir seedlings, although responding moderately to phosphorus fertilization, did not form mycorrhizae nor maintain normal growth rates. Excepting uninoculated Douglas fir, good growth in every instance was associated with high phosphorus absorption. The fact that Douglas fir made poorer growth on uninoculated, fertilized plots than on inoculated plots, even though seedling phosphorus levels were high, and no response was being obtained from nitrogen and potassium, suggests a mycorrhizal stimulus above that directly due to phosphorus. It is suggested that the stimulating effect of mycorrhizal fungi on conifer seedlings is due to heightened metabolism, associated in this instance with transfer of phosphorus and growth stimulators from fungus to seedling.

McComb, A. L. and F. L. Kapel 311

1940 Growth of seedling black locust and green ash in relation to subsoil acidity and fertility. J. For. 38: 228. fa

Planting experiments on an acid, infertile, glacial clay in southern Iowa showed that regardless of soil pH the seedlings of both species grew very poorly on unfertilized soil. The addition of nitrogen fertilizer alone had practically no effect on growth but the response to phosphorus fertilizer was tremendous, particularly for the black locust. Both species developed best at pH 4.3 with phosphorus treatment and at pH 6.9 without phosphorus.

McComb, A. L. and F. L. Kapel 312

1942 Effect of subsoil acidity and fertility on the growth of seedling black locust and green ash. Plant Physiol. 17: 7-15. A

One-year-old seedlings of black locust and green ash were grown in 4-gallon crocks on a yellowish brown, infertile, sticky clay of

pH 4.3, corresponding to the upper C horizon of the Lindley series. Four acidity levels were maintained—pH 4.3, 6.6, 6.9, and 7.7, with three fertility treatments at each acidity level: (1) no fertilizer; (2) nitrogen and potassium; (3) nitrogen-phosphorus-potassium.

The results at the end of a five-months' growth period showed that, regardless of soil pH, the seedlings of both species grew very poorly, if at all, when no fertilizer was added. Both species showed a tremendous response to N-P-K at all pH levels, and no response to nitrogen and potassium; this indicated that phosphorus was the element most limiting growth.

Both species developed best at pH 4.3 when phosphorus was added, and growth decreased as pH values increased. When phosphorus was omitted, growth of both species increased up to pH 6.9 and decreased again at pH 7.7. Green ash developed almost as well at the alkaline pH as at the other pH levels, while black locust grew very poorly at pH 7.7.

The results are interpreted largely in terms of phosphate availability. The fact that best growth occurred at pH 4.3 is attributed to the relatively high base saturation and the apparently adequate quantities of individually important bases.

The results also suggest the desirability of fertilizing seedlings when reforesting badly eroded sites of this soil series.

McDermott, R. E. and P. Y. Burns 313

1951 Effect of fertilizer on planted pine. J. For. 49: 633. A

Two seasons of growth of jack pine seedlings on eroded silty clay soils of central Missouri indicated that soil surface application of fertilizers at the time of planting does not increase height growth. Survival percentages on plots receiving nitrogen were particularly low due to a rank growth of tall weeds. A combination of calcium, phosphorus, potassium, but no nitrogen, resulted in few weeds, and a per cent survival that was almost as favorable as no fertilization.

McDermott, R. E. and P. W. Fletcher 314

1955 Influence of light and nutrition on color and growth of red cedar seedlings. Res. Bull. Mo. agric. Exp. Sta. 587. 15 pp. A

Seedlings of eastern red cedar grown under three light intensities and varying levels of nitrogen, calcium, phosphorus, and potassium indicated that fertilizers did not affect growth in any of the three

light intensities, and that growth responses in full sunlight and one-third sunlight were the same while one-tenth sunlight resulted in seedlings that were significantly stunted in height and top: root ratios. Fall color phases in red cedar foliage were found to be a direct result of sunlight intensity and independent of soil nutrition and microclimatic conditions pertaining to moisture stresses in the foliage and soil. Full sunlight resulted in a fall initiated red color, one-third sunlight in a yellow condition, and one-tenth sunlight resulted in a blue-green color that was unchanged from the summer condition of color under the same light intensity. The fall color changes of cedar foliage under the different light intensities were demonstrated to be closely allied with autumnal coloration in deciduous trees as evidenced by comparable foliage color changes in pin oak seedlings.

McIntyre, A. C. and J. W. White 315

1930 The growth of certain conifers as influenced by different fertilizer treatments. J. Amer. Soc. Agron. 22: 558-567. A

The experiments here reported were designed to test the value of certain commercial fertilizers for coniferous seedbed use and to determine if a single element, or a combination of elements, aid materially in producing vigorous seedlings in the field.

The fertilizers used were limestone ($CaCO_3$), 16% superphosphate (P_2O_5); KCl, 48% K_2O; $NaNO_3$, 15% N; $(NH_4)_2SO_4$, 20.5% N; dried blood, 8% N; also, white oak leaves and white pine needles, both finely ground. Amounts and combinations varied.

The studies showed that the three conifers used in these experiments were influenced in both their root and top development by the various fertilizers used, these responses varying with the soil type and the fertilizer.

In nearly all cases the seedlings grown on fertilized soil were larger, better developed, and heavier than those grown on the checks.

McIntyre, A. C. and J. W. White 316

1932 Fertilizing coniferous seedlings. J. Amer. Soc. Agron. 24: 72. A

It was found that after two additional years the growth response of pitch pine seedlings varied considerably, which it was assumed was probably due to certain fertilizers going into solution more

slowly than others or to the gradual removal of toxic concentrations of certain fertilizers.

McQuilkin, W. E. 317

1946 Use of mulch, fertilizer and large stock in planting clay sites. J. For. 44: 28-29.

McVicker, J. S. 318

1949 Composition of white oak leaves in Illinois as influenced by soil type and soil composition. Soil Sci. 68: 317-328. faA

Leaves from trees on various soil types were collected and analysed. Seasonal variations were observed, and the results of analyses were compared with data from studies of the physical and chemical properties of the soils. The percent of Ca in the leaf increased as the season advanced, whereas K, P, and N concentration decreased. Mg content remained fairly constant. Some evidence was obtained on the influence of soil type on the chemical composition of the leaf, but this was only significant when the poorest soils were compared to the best. No significant correlations were observed between the K, P. Mg and Ca contents or the Ca/Mg ratio of the leaves and the corresponding values for the A horizons. It is concluded that the roots can forage for the essential mineral nutrients to such an extent that they can take up amounts adequate for leaf growth even in soils comparatively low in replaceable bases. Other environmental factors expressed by the soil type, and possibly some not so expressed, apparently influence leaf composition.

Melvin, J. K. and A. L. McComb 319

1942 Response of American elm to loose and briquette fertilization in the greenhouse. J. For. 40: 49-51. faA

Eight fertilizer treatments, four loose and four in the form of briquettes, were applied to seedling American elms growing in the greenhouse on an acid in fertile clay subsoil of the Lindley series. At the end of five months, results for the loose treatments showed high significant responses to superphosphate used alone and to a combination of superphosphate plus ammonium sulphate, the latter being significantly greater than the former. No responses were obtained with ground rock phosphate or ammonium sulphate used alone in loose form, nor with any of the briquette treatments, apparently due largely to the failure of the roots to reach the briquettes.

MELVIN, E. AND H. NILSSON 320

1950 Transfer of radioactive phosphorus to pine seedlings by means of mycorrhizal hyphae. Physiol. Plant. 3: 88-92. fa

By the use of radioactive isotope, the authors were able to demonstrate that *Boletus variegatus*, as fungal symbiont, is able to transfer phosphorus to pine roots.

MELVIN, E. AND H. NILSSON 321

1952 Transport of labelled nitrogen from an ammonium source to pine seedlings through mycorrhizal mycelium. Svensk bot. Tidskr. 46: 281-285. fa

The tests were made with pine seedlings, growing in purified sand with added nutrient solution, and inoculated with mycelium of *Boletus variegatus*. The results showed clearly that there was a transference of the labelled N through the mycelia to the pine root.

MILLER, P. A. 322

1947 Spring pruning and fertilizing of California live oak trees cause increase of tip mildew. Calif. Agric. 1 (12): 4. fa

Fire-scorched trees of California live oak (*Quercus agrifolia*) in 2 areas burned over during the summer were severely attacked by tip mildew in the following spring and much of the new growth consisted of large witches' brooms. The transfer of seedlings from crowded flats or nursery rows to fertile soils in pots or in the field, also stimulates new growth, with a consequent increase in infection. Experimental work on possible control measures for this disease has been in progress since 1939. After 2 years' trial, spring pruning was abandoned as an aid to mildew control, the results having shown that the flush of growth following such pruning had an increased number of mildewed tips and of brooms. Application of N in the autumn had no adverse effect; application of ammonium sulphate in the spring resulted in an average of 15 more brooms per tree in treated trees than in controls. A similar group of trees which were at the same time pruned but not fertilized gave a roughly equal increase in brooming. It is recommended that pruning and fertilization of this species should be deferred till late summer or early autumn, when the weather is less favorable to the spread of the fungus and there is less young growth exposed to infection.

MIKOLA, P. 323

1953 (Some aspects of soil biology in silviculture). Metsät. Aikakausl. 1953: 258-262. (Finnish w/English summary) faA

Methods of preventing the formation of raw humus or of changing it to mull are discussed. These include: liming and mechanical cultivation, successfully practiced in Germany; growing tree species with a deep root system and high base content in the leaves; and burning slash and the upper part of the raw humus layer, as has been common practice in Sweden and Finland.

MITCHELL, H. L. 324

1934 Pot culture tests of forest soil fertility with observations on the effect of varied solar radiation and nutrient supply on the growth and nitrogen content of Scots and white pine seedlings. Black Rock For. Bull. 5, 138 pp. a

Scots pine and white pine seedlings were grown from weighed seed in pots protected from rain, adjusted for various levels of solar radiation, and treated with a basic nutrient solution containing varying nitrogen levels. Maximum total dry weight increased with nutrient levels of nitrogen up to 300 ppm. N. Further increase of N decreased total dry weight.

Nitrogen absorbed by soil-grown seedlings varied with the available phosphorus.

Rate of seedling increase in weight varied with nitrogen level and with solar radiation. Relatively higher N was necessary to bring out the effect of light intensity on yields.

Nitrogen supplying power of soil may be determined from percent nitrogen in seedlings.

MITCHELL, H. L. 325

1939 The growth and nutrition of white pine (*Pinus strobus*) seedlings in cultures with varying nitrogen, phosphorus, potassium, and calcium. Black Rock For. Bull. 9, 135 pp. a

Superior growth of pine seedlings was secured in soil whose nutrient concentration was kept in balance with the internal nutritive concentration of the vegetative tissue of the seedlings.

Seed size was discussed with reference to seedling size and soil nutritive concentration.

A method of adjusting soil fertility levels by periodic tests of soil and seedling is proposed.

Mitchell, H. L. and R. F. Chandler, Jr. 326

1939 The nitrogen nutrition and growth of certain deciduous trees of northeastern United States. Black Rock For. Bull. 11, 94 pp. a

Nitrogen content of leaves was found to vary with nitrogen level in soil. Within certain limits radial stem growth varies also with soil nitrogen level, thus leaf analysis provides a measure of site quality.

Hardwood species were grouped according to their tolerance of nitrogen deficiency; and the response to applied nitrogen was greatest in nitrogen–demanding species and least in the nitrogen-deficiency-tolerant species.

Mitchell, H. L. and R. F. Finn 327

1935 The relative feeding power of oaks and maples for soil phosphorus. Black Rock For. Pap. 1: 5-9. Ba

Four ¼ acre sample plots, established in a mixed hardwood stand, were given various amounts of rock phosphate in the spring. In the fall, leaf samples from red oak and red maple were analyzed for P content. The results showed an extremely high correlation between the amount of P applied and the P content of the leaves. In all cases, the P content of red maple leaves was approximately 100% higher than that of red oak leaves. Since red maple absorbs such relatively large amounts of P and redeposits it in an available form in the surface soil, the spp. should be retained in preference to those which have a lower nutrient content in their foliage.

Mitchell, H. L., R. F. Finn, and R. O. Rosendahl 328

1937 The relation between mycorrhizae and the growth and nutrient absorption of coniferous seedlings in nursery beds. Black Rock For. Pap. 1: 58-73. L

White pine and red spruce seedlings were grown for two seasons in a very infertile sand-sawdust-clay mixture, some seedbeds were unfertilized and others were fertilized with nitrogen, phosphorus, and potassium in various concentrations and combinations. Observations of these seedlings indicate that when appropriate fungi are present and other environmental factors are favorable, the frequency of incidence of ectotrophic mycorrhizae, and the degree of development on the roots of pine and spruce seedlings,

vary inversely as the concentration or readily available nutrient elements in the soil.

Comparison of infected and uninfected seedlings grown in the same nutrient environment revealed that mycorrhizal seedlings absorb significantly greater amounts of N, P, and K, and their dry weight increase is significantly greater than nonmycorrhizal seedlings.

MIYAZAKI, S., T. OKINAGA AND M. HARATA 329

1954 (The effect of fertilizer on the growth of black locust (*Robinia pseudoacacia L.*) Seedlings transplanted in Kosaka bare lands injured by strong sulphate smoke). Bull. Govt. For. Exp. Sta. Tokyo 74: 177-186. (Japanese) a

The soil is black and acid. Liming and application of NPK improved seedling growth.

MØLLER, C. M. 330

1954 Gødningsforsøg i skov (Experiments with fertilizers in forest). Dansk. Skovforen. Tidsskr. 39: 165-216. (Danish w/ English summary) fa

Describes the design of experiments laid out in 1953-1954 in young beech and Norway spruce plantations (about 20 of each) on representative sites, to study the influence of fertilizer treatment ($Ca(NO_3)_2$, KCl, or superphosphate) on height growth, and of a smaller investigation on the possible influence of fertilizer on basal area increment of young beech, and spruce. Tabulates results of soil analyses at the various sites and also summarizes results of investigations in Denmark, Sweden, Germany, Holland, Great Britain and the U.S.A. since about 1900.

MORELAND, D. E. 331

1950 A study of the translocation of radioactive phosphorus in loblolly pine (*P. taeda*). J. Elisha Mitchell sci. Soc. 66: 175-181. fa

A study was made of the rates, and paths of mineral-salt movement in *Pinus taeda*, using radioactive phosphorus P^{32} as a tracer. Rootlet tips were immersed in vials containing the phosphorus for periods up to 10 hrs. The rootlet was then severed and the tree felled. Cross-sectional root and stem samples were taken and

analyzed. The results are tabulated. The highest translocation rate obtained for P^{32} in the lateral roots was 1.42 m. per hr. The maximum determined rate for combined stem and root movement was 1.20 m. per hr. There were indications that movement is faster in the lateral roots than in the stem.

Morris, R. F. 332

1951 Tree injection experiments in the study of yellow birch dieback. For. Chron. 27: 313-329. fa

Tree injection experiments were carried out in New Brunswick in 1943-1944, to determine whether initial symptoms of dieback are associated with nutrient deficiencies. The tolerance of both yellow and white birch to nutrient salts was related to the weight of the salt injected; the concentration of the solution did not affect the leaf injury resulting from over-doses, but concentrations over 4% often killed a strip of cambium above the injection hole. The maximum tolerated dose varied with weather and condition of the tree. About 40 g. of a salt containing N, K, or P was the maximum that could be safely injected in dry weather. Injection of the maximum tolerated dose of these salts into trees showing initial symptoms of dieback produced no observable improvement in foliage color or radial growth in the current or following years. It is concluded that either these amounts are too small to affect the crown or deficiency in the three common elements is not a factor in dieback.

Mulder, E. G. and F. C. Gerretsen 333

1952 Soil manganese in relation to plant growth. Adv. Agron. 4: 221-227.

Müller, J. 334

1941 (The possibility of improving deteriorated forest soils by forestry-biological measures). Lesn. Práce 20: 94-128. (Czech w/German summary) fa

Methods of improving deteriorated sites by silvicultural measures and by working and fertilizing the soil are suggested for each of the numerous vegetation types and associations of Bohemia-Moravia.

Müller, P. E. 335

1922 Revision af forsøgskulturerne med gran i Gludsted plantage (Revision of the experimental spruce plantings at Gludsted). Forstl. Forsøysv. Danm. 6: 337-349. (Danish w/German summary)

Müller, P. E. and J. Helms 336

1913 Forsøg med anvendelsen af kunstgødning til hede kulturer i midtjydsk Hedebund (Experiments with artificial fertilizers on plantations on heath soils in Middle Jutland). Forstl. Forsøvsv. Danm. 3: 271-403. (Danish)

Multamäki, S. E. 337

1920 (On the swamps of Finland and their afforestation). Acta for. fenn. 16(5) 1-94. (Finnish w/German summary)

Muntz, H. H. 338

1944 Effects of compost and stand density upon longleaf and slash pine nursery stock. J. For. 42: 114-118. fa

Compost applied at the rate of one inch depth (approximately 23 tons dry weight per acre) resulted in increased top development, diameter growth, top-root length, root extent, and green weight of seedlings of *Pinus palustris* and *P. caribaea* and in a higher percentage of plantable seedlings than from untreated seedbeds. A study of varying conditions of stand density indicated that approximately 30 seedlings per sq. ft. would give best results, and that seedling density may be increased by the use of compost.

Heavier treatments of compost caused chlorosis in the pine seedlings; this was corrected by spraying with a one percent solution of $FeSO_4$.

Nafziger, J. 339

1940 Bodenuntersuchungsergebnisse zum Kalkdüngungsversuch 1 (Results of a soil analysis in connection with a liming experiment 1). Forstwiss. Zbl. 62: 59-64. fa

Soil investigations in connection with the liming experiments described by Fabricius showed that the rate of application—2,500 kg. $CaCO_3$ per ha.—was correct. Even after ten years the lime has been retained substantially in the top soil, of which the pH in limed plots was determined as 4.56, compared to 3.56 for that of unlimed plots.

NEILSON-JONES, W. 340

1943 Tree nutrition and soil fertility. J. For. 41: 886-888. fa

Investigations at the Wareham Forest have shown that the presence of a soil toxin tends to prevent both the introduction of short roots in Scots pine seedlings and the subsequent conversion of these roots into mycorrhizae. Under field conditions the activity of the toxin-producing organisms can be suppressed, and the development of mycorrhizae stimulated, by mixing with the soil various composts, which thereby produce conditions favorable to the vigorous growth of the seedlings. The judicious application of suitable composts helps to hasten the successional changes in soil microorganisms which normally accompany successional changes in surface vegetation in the transformation of grassland to woodland, and thus make it physiologically possible for trees to be planted successfully on such areas sooner than would otherwise be the case.

NĚMEC, A. 341

1931 (Studies on the effect of phosphoric acid fertilization on the growth of forest nursery stock). Zpr. výzkum. Úst. lesn. ČSR 49: 1-56. (Czech) A

In a number of forest nurseries experiments were carried out with a one-sided superphosphate fertilization (65-85 kg. P_2O_5 per ha) of spruce plants. The results were evaluated with consideration as to the chemical composition of the soil, the absorption by the soil of soluble phosphoric acid and the phosphoric-acid assimilation by the needles. No growth increase was attained on soils with a rather high reserve in P_2O_5 (250 mg. P_2O_5 soluble in 1% citric acid and 5 mg. of water per kg. of soil). On soils deficient in P_2O_5 the growth-increasing effect of the fertilization occurred only on soil with a sufficient reserve of assimilable lime and with not an excessive degree of acidity. The fertilization could not bring about a noticeable increase in growth on acid and lime-deficient soils, not even if the soil was lacking in P_2O_5. The effect of the fertilization is considerably reduced on soils high in easily soluble iron contents, and deficient in lime or with a higher degree of acidity. The negative effect of the Fe-compounds is not to be expected on soils rich in lime.

The soils which were extremely deficient in soluble P_2O_5, and on which the fertilization failed, absorbed 95 to 99% of the phos-

phoric acid, applied to the soil. Soils which reacted strongly to the fertilization, absorbed only 8 to 23% P_2O_5 of the fertilizer. The amounts of the phosphoric acid of the needles can also be used as an indicator of the nutrient requirement of the soil.

NĚMEC, A. 342

1932 a Über den Chlorgehalt des Bodens und die Wirkung von chlorhaltigen Kalisalzen auf das Fichtenwachstum in den Forstbaumschulen (On the chloride contents of the soil and the effect of chloride-containing potassium salts on the growth of spruce in forest nurseries). Forstarchiv. 8: 228-232. A

The effects of the fertilization of spruce seedlings with 40% potassium salt in forest nurseries depend on the chemical properties of the soil, in particular on its pH, potassium, lime and chloride contents. On acid soils which show higher chloride contents (10-44 mg Cl. in 1 kg. of soil) the fertilization with potassium, even on soils with a considerable deficiency of potassium, did not effect a noticeable increase in the growth of the spruce.

In soils with a maximum content of chloride (44-48 mg Cl. per kg. of soil) the potassium fertilization brought about a substantial decrease in the growth of the spruce, although these soils were the most deficient in potassium.

Favourable effects of 40% potassium fertilizers on the growth of spruce were recorded only on neutral or weakly alkaline soils, which showed an evident deficiency of easily soluble potassium compounds(less than 160 mg. K_2O, soluble in 1% citric acid or less than 3 mg. water soluble K_2O in 1 kg. of soil) and at the same time contained a small amount of water soluble chloride (less than 10 mg. Cl. in 1 kg. of soil).

The high chloride content of the soil, or the increase of chloride content in the soil due to fertilization resulted in an increased reassimilation of mineral nutrients by the spruce needles. It appears necessary in setting up a fertilization schedule for forest nurseries to consider not only potassium but also the chloride content of the soil.

On potassium deficient, yet chloride-rich, soils, chloride-free potassium fertilizers (potassium sulphate, patent kali) should be applied rather than the chloride containing potassium salts (40% and 50% potassium salts).

1932 b Untersuchungen über die Phosphorsäureernährung der Fichte in den Dauerkämpen (Investigations on the phosphoric acid nutrition of spruce in permanent forest nurseries). Forstwiss. Zbl. 54: 77-112. A

Reports of results of phosphorus fertilization experiments with spruce plants (80 kg. P_2O_5 in the form of superphosphate, per ha.). Experiments were carried out on 7 different soils which varied in texture, chemical characteristics, as well as in the absorption of soluble phosphoric acid by the soil. Also the phosphoric acid absorption by the needles was taken into consideration. Soils with sufficient phosphoric acid contents (more than 250 mg. P_2O_5, soluble in 1% citric acid and more than 5 mg. water soluble P_2O_5 in 1 kg. of soil) did not show any increased growth.

Deficient soils, fertilized with P_2O_5 showed an increased growth effect; however, only where sufficient lime was available, substantially acid soils (pH (KCl) = 4.0) with insufficient lime contents (exchangeable CaO 100-150 mg. in 100 grams of soil) did not respond to P_2O_5-fertilization. A laboratory determination of the absorption curve of the soil for water soluble phosphoric acid offers the possibility of determining the approximate dose of fertilizer, which is necessary to assure an optimum effect of the P_2O_5 fertilization on the growth of the spruce under the given conditions.

The phosphoric acid requirement of the soil can not only be estimated by a direct determination of the easily soluble reserve of P_2O_5 and the absorption capacity of the soil for the phosphoric acid fertilizer but also on the basis of the amount of P_2O_5 reassimilated by the needles.

Němec, A. 344

1932 c Étude sur la teneur du sol en chlore, et sur l'action des engrais potassiques sur la croissance du pin dans les pépinières forestières (Study on the amount of chloride in the soil and on the effect of potassium fertilizers on the growth of pine in forest nurseries). Rev. Eaux. For. 70: 373-379. Ba

During 1929 and 1930 experiments were made with 1-year pines (*P. sylvestris*) in nurseries of Bohemia and Moravia to determine the effects on height growth and mineral content of the leaves

caused by chemical fertilizers containing 40% K_2O, and the relation of the variable effects to pH, total K_2O, water soluble K_2O, K_2O soluble in 1% citric acid, and water soluble Cl. of the soil sampled to a depth of 20 cm. Fertilizing neutral or alkaline soils improved height growth only when K was deficient (less than 160 mg. acid soluble, or 30 mg. water soluble per kg. of soil) and water soluble Cl. was low (less than 10 mg. per kg. of soil). With acid soils having 10-44 mg. water soluble Cl. per kg. of soil, even though markedly deficient in K, growth was not improved. With the higher concentrations of Cl. growth was retarded. The mineral content of leaves (ash in % dry weight) was highest for plants grown in soils rich in Cl. Fertilizing soils poor in Cl. increased the mineral content of leaves, but produced no change with soils rich in Cl. The K_2O content of leaves (in % of dry weight and of ash) was greater for plants grown in soils with higher K_2O content. Leaves of plants grown in soils fertilized with 40% K_2O had uniformly lower percentages of K_2O in the ash than those from plants grown in untreated soils. The K_2O content was sometimes higher, sometimes lower, for fertilized than for unfertilized soils. It was decreased by fertilizing soils rich in Cl., but increased by fertilizing soils poor in Cl. Nursery soils should be examined for Cl. and K_2O before applying K fertilizers. For soils poor in K_2O but rich in Cl., sulfates of potassium are suggested.

NĚMEC, A. 345

1933 a Essais sur la fumure azotée des plants d'épicéa dans les pépinières (Experiments relating to the nitrogen fertilization of spruce plants in forest nurseries). C. R. Congr. for. Nancy 1932: 611-623. A

Experiments involving fertilization of 1-year spruce plants with a one-sided application of nitrogen (60 kg. per ha) in the form of chilisaltpeter, calcium nitrate and ammonium sulphate were carried out in various forest nurseries. On soils with alkaline reaction, ammonium sulphate gave more favorable results than chilisaltpeter or calcium nitrate. The effect of the nitrogen fertilization on these soils decreases with an increase in soluble nitrogen content of the soil. The results of fertilization on acid soils were less favorable than on alkaline soils. Chilisaltpeter and calcium nitrate had a more favorable effect than ammonium sulphate on the height growth of the spruce. The effect of the nitrogen fertilization was

more favorable on soils with a low content of soluble nitrogen. The forest nursery soils where the experiments were set up were very deficient in lime, potassium and phosphoric acid. The nitrogen assimilation of the needles increases on unfertilized alkaline soils with an increase of the soluble nitrogen content of the soil. In the case of acid soils the nitrogen content of the needles decreases. After a reapplication of nitrogen fertilizer on alkaline soils, the N-content of the needles increased directly with the amount of soluble nitrogen in the original soil. The N-content of the needles of spruce on the acid soils reflects a similar response. The content of mineral substances in needles poor in ash is increased by nitrogen fertilization; The ash rich spruce needles on the other hand show a reduction in the content of mineral substances with a one-sided application of nitrogen fertilizer.

NĚMEC, A. 346

1933 b (Results of the fertilization experiments with artificial fertilizers in forest nurseries). Rec. Inst. Rech. agron. Rép. tchécosl. 81: 71 pp. (Czech) A

Reports the results of the experiments carried out in the years 1929-1930, and which were concerned with the one-sided fertilization of spruce and pine in forest nurseries with sodium- and calcium nitrate, ammonium sulphate, 40% potassium salt, superphosphate and quicklime, applied in amounts corresponding to 60 kg. N, 120 kg. K_2O, 90 kg. P_2O_5 per ha and 20 kg. CaO per 100 sq. meter. Chemical properties of the soil (acidity, nutrient content) were taken into consideration. The smallest growth increased was only observed on soil with extreme reaction (pH = 7.5 and pH = 2.98). Strongly acid and alkaline soils retard the growth of spruce. Ammonium sulphate has a more favorable effect than nitrate on neutral and alkaline soils, on acid soils the opposite is true. Otherwise the effect depends on the nitrogen content of the soil. Potassium fertilization is most effective on potassium- and chlorine- deficient and weakly alkaline or neutral soils. On acid soils with a higher Cl content (10-45 mg. Cl. per kg. of soil) there is no increase in growth, rather a decrease in spite of a potassium deficiency. On lime deficient soils, the one-sided lime application increased growth only after three to four years, and then only when other sufficient nutrients in the soil were available. The effect of fertilizing on the nutrient assimilation by the needles was also investigated.

Němec, A. 347

1933 c (The influence of the cultivation of lupines upon forest soils). Lesn. Práce 12: 457-465. (Czech) Ba

The N, CaO, K, and P_2O_5 contents of the soil and the soil acidity were determined in sample plots of Norway spruce plantations of the Milevsko region, southern Bohemia. Soil analyses of plots on which *Lupinus polyphyllus* was cultivated to foster development of spruce showed a considerable gain in N content over those not treated with lupine. Lime also increased in the treated plots, especially in the surface soil layers. There was no increase in K, and P_2O_5 in lupine treated plots, but their acidity decreased. The needles of spruce grown in stands with lupine contained more N than in non-treated plots, but lacked in substances (cellulose, resins, etc.) causing lignification and rigidity of needles.

Němec, A. 348

1934 (The effect of the chemical condition of the soil on the growth and mineral constituents of lupine in forest nurseries). Lesn. Práce 13: 483-498. (Czech) A

Reports 12 comparative studies concerned with the growth of one-year-old, white, blue and yellow lupine, which were sown on various forest nursery soils for the purpose of green manuring. It was shown that besides the climatological factors and the soil texture, the chemical properties of the soil in particular, influence the growth of the lupine. The lupines, including the yellow lupine, showed poor growth on strong acid soil (pH 3.6-4.1). The germination capacity of the white lupine is most sensitive to the acid reaction of the soil. Growth increment and yields increase with a decrease of the acidity of the soil, the maximum lying in between a pH of 6.1-6.9. The aerial parts of the blue lupine were higher in lime content than those of the white or yellow lupine. The nitrogen content of the leaves and stems was independent of the nitrogen content of the soil. The blue and white lupine showed the highest N-content on soils well supplied with lime. Lupine also requires a sufficient phosphoric acid content of the soil, upon which also depends the N-content of the plants. A deficiency of soil phosphoric acid decreases the P_2O_5 and N-content of the plants and therefore decreases the manurial value of the lupine. In order to secure a successful manuring with lupine, the experiments have shown the necessity of liming on acid and lime-deficient soils and the phosphorus fertilization of P_2O_5-deficient soils in forest nurseries.

1935 a (Results of green manuring experiments in forest nurseries). Rec. Inst. Rech. agron. Rép. tchécosl. 134: 1-120. (Czech) A

In the first part the results are reported of experiments with various kinds of green manure plants in forest nurseries, (yellow, white and blue lupine, horsebeans, vetch, villous vetch and seradella), in relation to the properties of the soil as well as the nutrient content of the plants. Blue lupine gave the highest yield and seradella the lowest. Heavy soils are suitable for white lupine; for blue lupine the medium and lighter soil types; for yellow lupine the light sandy soils; for vetch and villous vetch the medium soils; and almost all soil types for the horsebeans. Seradella requires a moister soil, in case of lack of moisture, the medium and heavy soils are more favorable than the light sandy soils. Unsuitable for villous vetch are the heavy soils, for yellow lupine the medium soils and for vetch the light soils. Of the chemical properties of the soil the acidity and the lime content in particular were controlling factors. The yields of both lupine and seradella show two optimums. The first and lower yield where soil reaction is strongly acid (pH 4.2-4.6), the second and higher optimum where soil reaction is weakly acid (6.0-6.4). The remaining papilionaceous plants show also a similar behaviour, with the exception of vetch, which only gave an optimum yield at a pH of 4.5. Extreme acidity of the soil (pH 3.6-4.0) result in a considerable decrease of production. The amounts of nitrogen produced by the aerial parts were highest for villous vetch and horsebean; seradella produced the minimum amount of 61 kg. N/ha.

The second part reports in detail the results of the green manuring of the growth of one-year-old spruce seedlings. A distinct increase of plant heights was obtained only at maximum nitrogen content of green manure plants on nitrogen deficient soils (32.45 mg. soluble N per 1 kg. soil; 0.19&-0.20% total nitrogen). The green manuring of the spruce failed where the soil had a greater reserve of nitrogen.

Němec, A. 350

1935 b Über den Einfluss der Phosphorsäuredüngung auf das Fichtenwachstum in den Pflanzgärten (The effect of phosphoric acid fertilization on the growth of nursery spruce). Phosphorsäure 4: 695-705. A

Reports of the effect of phosphoric acid fertilization (1.2 kg. P_2O_5 in the first year and 0.6 kg. of P_2O_5 in the form of Thomas slag in the second year) on one-year-old transplanted spruce seedlings on various forest nursery soils. The fertilization had no effect on the growth and did not result in an increased P_2O_5-content of the needles when plants had high phosphoric acid contents (over 0.8% P_2O_5 in the dry matter of the needles) and were growing on soils with sufficient P_2O_5 (with content of 250 mg. P_2O_5 soluble in 1% citric acid, per 1 kg. of soil) phosphoric acid assimilation by the needles (0.5-0.8%) and growth were increased when needles had an average P_2O_5 content (0.5-0.8%), with few exceptions, which could be blamed to various factors such as moisture deficiency, absorption in the soil, etc.

The lowest P_2O_5 contents of needles occurs in the most P_2O_5-deficient soils, in combination with considerable increase in growth of the spruce. Further the effect on spruce plants is described in terms of increased P_2O_5 applications in the form of superphosphate and Thomas slag on phosphoric acid deficient soils. Greatest growth increment was found with the Thomas slag fertilization. Finally, the results are reported of the fertilization with superphosphate and Thomas slag of stagnated spruce plantations on a clear-cut area. It was found that in the course of the first year after the fertilization that Thomas slag had a better effect than superphosphate.

NĚMEC, A. 351

1935 c (Experiments relating to the effect of green manuring on the growth of transplants in forest nurseries). Lesn. Práce 14: 85-91. (Czech) A

Green manuring experiments were carried out with leguminose plants (suitable for the site) in various forest nurseries. Preliminary experiments were made to determine the green manure plants most suitable for the site. The green manuring experiment was laid out in the following year. When the area was seeded in, no fertilizers or manure was applied. The results of the experiments showed that a growth increment of forest plants (spruce, pine, ash) following green manuring, only takes place on nutrient deficient, especially nitrogen deficient, soils. A favorable effect of the green manuring was found on soils poor in humus, with a total nitrogen content of 0.053-0.134% and 29.5-44.1 mg. soluble nitrogen (per 1 kg. of soil) and of which the N/loss on ignition ratio fluctuated between

1.8-2.0%. No growth stimulating effect of the green manure could be observed on soils rich in nutrients, with a total nitrogen content of 0.158-0.344% and 68.9-73.9 mg. soluble nitrogen (per 1 kg. of soil) and with a N/loss-on-ignition ratio of 2.6-3.1.

NĚMEC, A. 352

1935 d (Contribution to the knowledge of the chemistry of the deficiency symptoms in pine). Lesn. Práce 14: 442-451. (Czech) A

It has been established that the typical dull purple discoloration of pine needles in the fall is associated with soil mineral deficiencies. The deficiency-symptoms are also characteristic of shifts in the P_2O_5:K_2O:N ratio of the needles. This ratio in healthy pine plants with normal nutrient content is about 1:1.5:3.6.

Discolored needles of pine growing on P_2O_5 and potassium deficient soil were found to have a ratio of 1.0:2.1:5.3. A superphosphate or Thomas slag fertilization changed the contrasting nutrient ratio of the needles into one, almost normal, ratio of 1.0:1.6:3.5 to 1.0:1.5:4.0.

NĚMEC, A. 353

1936 a (Experiments relating to the influence of phosphate fertilizers on the growth of spruce on the Pläner limestone soils in the forest district Pátec on the Elbe). Ann. Acad. tchécosl. Agric. 11:36-48. (Czech w/German summary) A

Reports the effect on one-year-old spruce seedlings of increasing rates of phosphoric acid fertilizer in the form of superphosphate and Thomas slag in combination with ammonium sulphate and potassium salt on a phosphoric acid- and potassium- deficient, limy (Pläner lime), sandy loam nursery soil. Of the five different levels of phosphoric acid, the largest amount (240 kg. P_2O_5 per ha) corresponded to the rate which seemed necessary to bring the phosphoric acid content of the soil to the optimum level (250 mg. P_2O_5 in 1 kg. of soil, soluble in 1% citric acid). The highest height increase was obtained with Thomas slag, corresponding to 120 kg. P_2O_5 per ha. The maximum green weight of 3-year-old spruce seedlings was obtained with the largest P_2O_5 application (250 kg. P_2O_5 per ha). The production of plant material was promoted much more intensively than the height growth. The effect of the

fertilization is also quite noticeable in the nutrient assimilation of the spruce needles. The P_2O_5-fertilization increased the phosphoric acid content as well as the potassium and lime contents of both the dry matter and the ash of the needles. The phosphoric acid fertilization had further a favorable effect upon the P_2O_5/N-ratio, so that this came close to the ratio of normally fertilized spruce.

The pentosan and extractibles (Benzol-Alcohol-Extract) content of the needles was not noticeably effected by the fertilization.

Similar results were obtained with a single application of phosphoric acid fertilizer, whereby the growth of the spruce after transplanting on clear-cut areas was observed. The favorable effect of the fertilization in the nursery remained for many years.

Němec, A. 354

1936 b (Studies on the deficiency symptoms in pine in the forest nursery Revnice). Ann. Acad. tchéchosl. Agric. 11: 531-534. (Czech) A

Further research is reported on the nutrient content of nutrient-deficient sandy loam soil (weathered silurium-shale) and the needles of pine seedlings in a forest nursery. The soil of the rooting zone of pine seedlings, which showed purple colored needles, had a considerably lower content in easily soluble phosphoric acid than that of other healthy green seedlings in the same nursery. No differences were observed in the nitrogen, potassium and magnesium content, only the lime concentration was a little lower. The purple colored pine needles were considerably more deficient in phosphoric acid and lime than the green-colored needles. The deficiency symptom is therefore caused by an insufficient uptake of P_2O_5 and CaO by the pine seedlings. By fertilization with phosphoric acid the purple color of the needles disappeared.

Němec, A. 355

1936 c Zur Kenntnis der Karenzerscheinungen bei der Kiefer (Deficiency symptoms of the pine). Congr. Un. int. Rech. for. (Budapest) 1936. A

Chemical analyses of green, brownish-green and purple colored needles of the pine seedlings of a nursery (clayey sand, very deficient in phosphoric acid and potassium) have established that a remarkable decrease in potassium re-assimilation and a reduction in

silicic-acid, sulphuric acid and of phosphoric acid takes place in the brownish-green needles, while the phosphoric acid content of the dull purple needles is strongly reduced. The brown discoloration of the pine needles is mainly caused by a potassium deficiency. The P_2O_5-K_2O-N ratio of 1.2-1.4-0 in the green needles shifts to the ratio 1.1-0.3-6 in the brownish-green needles. The nutrient ratio is restored almost back to normal by fertilization.

NĚMEC, A. 356

1937 a (Experiments on the fertilization of ash with magnesium-rich limestone dust in the forest nursery Revnice). Čsl. Háj, 14: 141-144. (Czech) A

Reports an experiment on the fertilization of ash with dolomitic limestone, applied at different rates, on a nutrient-deficient soil, low in lime content, at a nursery in the neighborhood of Prague. The lime requirement, determined after *Daikuhara*, amounted to 50 kg. of $CaCO_3$ per 100 sq. meter. The amounts of limestone used corresponded to 20, 40 and 60 kg. per 100 sq. meter and half of the amounts were applied in two consecutive years. At the end of the 2 years of the experiment the resulting increased height growth amounted to 38, 40 and 50% in comparison to the unfertilized control plots. The most favorable effect was obtained with that quantity of lime applied, which closely resembled the amount required, as determined by the soil analysis after *Daikuhara*.

NĚMEC, A. 357

1937 b (The effect of a one-sided N fertilization upon the growth of spruce in forest nurseries). Ann. Acad. tchécosl. Agric. 12: 32-47. (Czech w/German and Russian summaries) A

No growth stimulating effect could be found from excess N fertilization of soils very deficient in P_2O_5 and CaO; on strongly acid soils even a decreased growth was observed.

On favorable soils, in good nutrient condition (more than 100 mg. P_2O_5 per 1 kg. soluble in 1% citric acid) fertilization was found to have a favorable effect. The nitrate fertilizers proved to be more effective on strongly acid soils than on medium acid soils; ammonium sulphate worked better on medium acid soils than on strongly acid soils.

Němec, A. 358

1937 c (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. I. The effect on the uptake of nitrogen). Ann. Acad. tchécosl. Agric. 12; 141-149. (Czech w/German summary) Ba

One-year spruce seedlings were fertilized with $NaNO_3$ $Ca(NO_3)_2$, and $(NH_4)_2SO_4$ at the rate of 0.9 kg. N per 100 sq. m. The 2nd year 0.3 kg. was applied. In unfertilized beds the N content of the foliage increased as growth intensity declined. Application of nitrates decreased assimilation of N by the foliage in beds where the soil already contained abundant N, but increased it where N was deficient. The effect of fertilization in the 3rd year was influenced by the quantity of P_2O_5 in the soil. Application of $(NH_4)_2SO_4$ resulted in 14% increase in N content of needles when both N and P_2O_5 were deficient, but $NaNO_3$ caused only a slight increase; with adequate P_2O_5 but deficient N, both nitrates caused an increase of 7.6-8.9%; with abundant N and P_2O_5 application of nitrates resulted in 13.1% decrease in N content; and with adequate N but deficient P_2O_5 the reduction was 1%. The largest increase was in soils with abundant P_2O_5 but deficiency of lime. On soils poor in N but with abundant P_2O_5 the N content of the needles varied directly with the lime content of the soil.

Němec, A. 359

1937 d (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. II. The effect on the uptake of phosphoric acid). Ann. Acad. tchécosl. Agric. 12: 209-215. (Czech w/German summary)

Němec, A. 360

1937 e (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. III. The effect on the uptake of potassium. IV. The effect on the uptake of calcium). Ann. Acad. tchécosl. Agric. 12: 385-391, 391-398. (Czech w/German summary) Ba

One-year spruce transplants were fertilized with various nitrates, and after 2 years the CaO and K_2O content of the needles was studied. Assimilation of K_2O depends on the amount of K compounds in the soil that are capable of assimilation by plants; the highest % of K_2O was in the needles of spruce grown on the soil that was richest in K_2O. Application of nitrates resulted in de-

creased assimilation of K, except on soil with greatest K_2O deficiency, where $NaNO_3$ caused a slight increase. $(NH_4)_2SO_4$ reduced K_2O assimilation the most, $NaNO_3$ the least. On soils with sufficient P_2O_5 and lime, but deficient in K_2O, application of nitrates led to an increase in K_2O assimilation, but not on acid soils deficient in lime, except where these also lacked P_2O_5. Assimilation of K_2O and P_2O_5 was increased on soils poor in soluble nitrates when $Ca(NO_3)_2$ and $NaNO_3$ were applied, but not with $(NH_4)_2SO_4$. CaO content of the needles varies directly with the quantity of CaO in the soil. Application of nitrates caused an increase in CaO assimilation on soils deficient in lime and a decrease on those rich in lime. On soils containing sufficient P_2O_5 the CaO content of the needles was increased only in fairly acid soils deficient in lime; when P_2O_5 was deficient, CaO assimilation increased only on soils with little soluble N. On acid soils deficient in CaO and P_2O_5 nitrates increased CaO assimilation.

NĚMEC, A. 361

1937 f (The effect of a one-sided N fertilization upon the losses of transplanted spruce in forest nurseries). Ann. Acad. tchécosl. Agric. 12: 461-469. (Czech w/German summary) A

The failure of spruce on unfertilized beds increases with decreased precipitation. An application of sodium nitrate, calcium nitrate and ammonium sulphate three to six weeks before transplanting did not increase mortality. Fertilization had an unfavorable effect when the fertilizers (especially sodium nitrate) were applied a short time before or at the time of transplanting. Sodium nitrate should be applied at least three weeks before transplanting of one-year-old spruce. Calcium nitrate and ammonium sulphate can be applied 10-14 days before transplanting, without increasing plant losses. As top dressing only calcium nitrate and ammonium sulphate are suitable about 3-4 weeks after transplanting. Due to the physiological acid or alkaline reaction of the fertilizers the unfavorable effect of the soil reaction was corrected or increased.

NĚMEC, A. 362

1937 g (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. V. The effect on the uptake of magnesia). Ann. Acad. tchécosl. Agric. 12: 545-557. (Czech w/German summary) Ba

Assimilation of MgO on unfertilized soil increased with the MgO content of the soil. Where there was sufficient P_2O_5 in the soil, application of nitrates increased MgO assimilation only on weakly acid or neutral soil. Where P_2O_5 was deficient, assimilation decreased after application of nitrates except that $(NH_4)_2SO_4$ increased assimilation when relative soluble N was less than 3%. When the "relative lime factor" (CaO/MgO) was low, assimilation of MgO decreased with application of nitrates.

NĚMEC, A. 363

1937 h (The effect of a one-sided phosphate application on the growth of nursery spruce). Ann. Acad. tchécosl. Agric. 12: 631-641. (Czech w/German summary) A

The fertilizer was applied in the form of superphosphate or Thomas slag. An amount of 100 mg. P_2O_5, soluble in 1% citric acid, per 1 kg. soil can be considered a marginal value, to distinguish the P_2O_5-deficient soil from the soil with sufficient P_2O_5, for the growth of 3-year-old spruce plants. This marginal value was also confirmed by the calculated requirement of spruce for P_2O_5.

On strongly acid and deficient soils, the fertilization did not result in an increased growth of spruce. Where the potassium reserve of the soil was more favorable, the fertilization resulted in increased growth. Thomas slag accomplished more than superphosphate on strongly acid soils. On weaker acid soils the effect of the fertilization was smaller.

The favorable effect of a one-sided P_2O_5 fertilization occurs only if a harmonious relationship is established between phosphoric acid, potassium and lime in the soil as a result of the phosphoric acid application.

NĚMEC, A. 364

1937 i (The effect of a one-sided P_2O_5 fertilization on the nutrition of spruce plants in forest nurseries. I. The effect on the nitrogen uptake). Ann. Acad. tchécosl. Agric. 12: 641-647. (Czech w/German summary) Ba

The N content of needles of spruce seedlings increases decidedly from the 1st to the 3rd year on soil rich in lime, but decreases on acid soils. Application of P_2O_5 fertilizers (superphosphate and Thomas-meal) tended to reduce the N content of needles where the soil was rich in N, but to increase it where N was deficient.

On soils with a fair content of P_2O_5 addition of the fertilizer was followed by increased assimilation of N on soils where the relative solubility of N compounds (in 1% K_2SO_4 soln.) was fairly high, and by reduced assimilation where the relative solubility was low. On soils with low P_2O_5 content addition of the fertilizers was generally followed by reduced assimilation of N.

NĚMEC, A. 365

1938 a Untersuchungen über den Einfluss der Phosphorsäuredüngung auf das Wachstum und auf die Ernährung der Fichte in Waldbaumschulen (Investigations on the effect of phosphoric acid fertilizing on the growth and nutrition of spruce in forest nurseries). Bodenk. u. PflErnähr. 11: 93-128. A

The effect of a one-sided application of superphosphate and Thomas slag on the growth of spruce seedlings depends on the P_2O_5 content of the soil. The amount of 160 gr. of P_2O_5 in one kg. of soil, soluble in 1% citric acid is the marginal value, distinguishing P_2O_5 deficient soils from the soils containing sufficient P_2O_5.

One-sided fertilization on a P_2O_5 deficient soil will only result in an increase in growth, if by the application a harmonious relationship is established between the principal nutrients. No growth increase is obtained on extremely acid, lime, and potassium deficient soils. On the other hand, fertilization with superphosphate and, in particular, with Thomas slag, increased growth considerably on P_2O_5 deficient soils which were well supplied with potassium. On strongly acid soils (pH 3.2-4.0) Thomas slag had more effect than superphosphate. The fertilization did not cause a noticeable increase in spruce losses, even when the application took place at the time of transplanting.

Further, a detailed report is given regarding the effect of a one-sided phosphoric acid fertilization on the nitrogen, phosphoric acid, potassium, lime, magnesium, manganese, iron and aluminum assimilation by the spruce needles, under conditions of changing acidity and nutrient content of the soil.

NĚMEC, A. 366

1938 b (Fertilization experiments with forest soils in combination with intercultivation of agricultural crops in the Malacky military forest). Ann. Acad. tchécosl. Agric. 13: 638-649. (Czech w/German summary) A

The forested parts of the extensive drift sand area in western Slovakia are mainly covered by pine and oak stands. The fine-textured sandy soils in this semi-arid district suffer from a serious lack of precipitation and principal nutrients. Reforestation is carried out in combination with field crops. After the stumps are uprooted, the soil is mechanically loosened and seeded in with one- or two-year rye (forest rye), millet or potatoes. Field cropping is carried on for 2 to 4 years and only then pine is planted.

The soils suffer from a serious deficiency in phosphoric acid and potassium and, in spite of insufficient lime contents, are only weakly acid. Nitrogen content is more favorable. Agricultural yields are very low.

When field cropping is economically dependent on the size of the yields, experiments with artificial fertilizers are established in order to increase the production. Increases of rye yield were small. Thomas slag and potassium salt fertilization of forest meadows showed a much better effect (increases up to 20% to 37%). The effect on potato production was of particular significance. The complete NPK fertilizer increased the tuber production by 62%, the leaf production by 274%. The phosphoric acid and potassium assimilation by the tubers had increased considerably. Analyses of potato crops have shown that growth of potatoes on forest land in combination with a complete fertilizer application does not deplete the soil in nutrients provided the potato foliage is plowed into the soil. Pine, planted simultaneously in between potato rows are stimulated to better growth by the phosphoric acid and potassium remaining in the soil.

NĚMEC, A. 367

1938 c (The influence of liming on the growth of spruce in forest nurseries). Lesn. Práce 17: 209-234. (Czech w/ German summary) A

In a series of experiments on various forest nursery soils, the effect of one-sided application of quicklime (500 gr. lime per $5m^2$ area) on 1-year old spruce plants were evaluated with respect to climatic conditions and the chemical properties of the soil:

1. Losses of spruce plants—The plant losses on unfertilized beds were mainly caused by lack of precipitation. Considerable losses occurred when the total amount of rain from April to August went down to below 300 mm. Further, the losses depend on the time lapse between fertilization and the transplanting of the spruce

seedlings. With a time lapse of 3-6 weeks the differences in losses between untreated and limed beds were quite small, regardless of whether the liming took place before or after transplanting. With a shorter time interval (up to 3 weeks) the losses were higher on limed soils (4 to 5.5%). The highest losses occurred on soils with a maximum lime content. With regard to the influence of soil texture, the lightest soils showed greater losses as a result of fertilization with quicklime than the medium textured soils.

2. Growth increment of the spruce—Liming had a growth-stimulating effect only on soil containing sufficient P_2O_5 with a pH of 4.33-4.70, provided the lime application corresponded to more than 45% of the actual lime requirement of the soil. On soils rich in lime, liming had a light adverse effect on the growth of spruce. On soils with insufficient P_2O_5 content, and on lime-deficient soils, the one-sided lime fertilization showed in general no stimulation of the growth of spruce. The effect of liming depends in the first place on the acidity and nutrient condition of the soil.

NĚMEC, A. 368

1938 d (Chlorosis of seedlings and stunted plantations of Scotch pine). Lesn. Práce 17: 388-402. (Czech w/German and French summaries) A

Yellowing of needles, which occurs on soils extremely deficient in potassium and magnesium, was examined in pine seedlings on a strongly acid and nutrient-deficient sandy soil. The considerable decrease of potassium and magnesium content of the needles and wood of the pine was accompanied by a considerable increase in the manganese assimilation. Similar observations were also made with the foliage and twig wood of deformed pine in older plantations showing yellowing of the needles.

A remedy to recover growth and to counteract the yellowing of the needles was obtained through an application of potassium fertilizers and of dolomitic limestone.

NĚMEC, A. 369

1938 e (The effect of a one-sided P_2O_5 fertilization on the nutrition of spruce plants in forest nurseries. II. The effect on the uptake of phosphoric acid. III. The effect on the uptake of potash and calcium. IV. The effect on the uptake of magnesia). Ann. Acad. tchécosl. Agric. 13: 48-57, 101-109, 109-116. (Czech w/German summary) Ba

Seed beds were fertilized with phosphates at the rate of 1.2 kg. P_2O_5 per sq. m. the 1st year and 0.4 kg. the 2nd year. In the 3rd year assimilation of P_2O_5 had been reduced on plots that already had more than 160 mg. P_2O_5 (soluble in 1% citric acid) per kg. of soil, as well as on plots with less P_2O_5 that were also deficient in N, but was increased on plots deficient in P_2O_5 but with sufficient N. Similar fertilization had little effect on assimilation of K_2O on soils with abundant P_2O_5 and K_2O, but was followed by increased assimilation on neutral or weakly acid soils deficient in K_2O. Assimilation of CaO was increased considerably on lime deficient soils, especially those also deficient P_2O_5. On soils with more than 100 mg. P_2O_5 per kg. of soil and a fair amount of available MgO, application of P_2O_5 fertilizer had no effect on assimilation of MgO. On neutral soils deficient in MgO assimilation was increased following the use of fertilizer. On acid soils deficient in P_2O_5 and MgO assimilation was increased.

NĚMEC, A. 370

1938 f (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. VI. The effect on the uptake of manganese. VII. The effect on the uptake of silica). Ann. Acad. tchécosl. Agric. 13: 256-265, 266-273. (Czech w/German summary) Ba

On soils with high lime content spruce needles contained little MnO. A slight change in MnO absorption followed fertilizing with $NaNO_3$, but application of $Ca(NO_3)_2$ resulted in considerable increase and $(NH_4)_2SO_4$ a large increase in MnO absorption, particularly on the more acid soils. The maximum intake was on very acid soils with abundant MnO. The SiO_2 content of the needles increased with decrease in P_2O_5 content of the soil. N fertilizing was followed by decrease in P_2O_5 and increase of SiO_2 content of the needles. $(NH_4)_2SO_4$ was most effective in this respect.

NĚMEC, A. 371

1938 g (The effect of a one-sided N fertilization on the nutrition of spruce plants in forest nurseries. VIII. The effect on the uptake of iron and aluminum). Ann. Acad. tchécosl. Agric. 13: 445-455. (Czech w/German summary) Ba

Applications of nitrates, especially $(NH_4)SO_4$, on soils containing fair amounts of P_2O_5 resulted in increased Fe_2O_3 content of spruce needles. On soils with less than 100 mg. P_2O_5 per kg., there

was little or no increase in Fe_2O_3 with $NaNO_3$ or $Ca(NO_3)_2$, but there was an increase with $(NH_4)_2SO_4$. On untreated soil the Fe_2O_3 content of the needles was greater with greater relative solubility of soil nitrates; addition of $NaNO_3$ or $Ca(NO_3)_2$ resulted in greater Fe_2O_3 content only on soils with low nitrate solubility, but $(NH_4)_2SO_4$ increased it on all soils. On untreated acid soil the needles contained more Fe_2O_3 than on neutral soils. The Fe_2O_3 content was increased by each of the 3 fertilizers on soils with pH greater than 4.0, but was decreased by addition of $Ca(NO_3)_2$ and $(NH_4)_2SO_4$ on more acid soils. The Al_2O_3 content of needles varied directly with that of the soil. Application of $(NH_4)_2SO_4$ resulted in greater intake of Al_2O_3 on all soils, but with the two nitrates only on soil poor in Al_2O_3. On very acid soils the plants took up more Al_2O_3 than on slightly acid or neutral soils. On the latter soils, application of $(NH_4)_2SO_4$ resulted in a large increase in Al_2O_3 intake, but the other 2 fertilizers had little effect.

Němec, A. 372

1938 h (The effect of a one-sided P_2O_5 fertilization on the nutrition of spruce plants in forest nurseries. V. The effect on the uptake of manganese). Ann. Acad. tchécosl. Agric. 13: 649-657. (Czech w/German summary) Ba

The intake of Mn by spruce needles depends on soil acidity and the content of readily soluble Mn compounds in the soil; it varies inversely with CaO and MgO content. Fertilizing with P_2O_5 increases Mn intake on neutral and acid soils. On soils rich in Mn but poor in P_2O_5, fertilizing increases the intake of Mn but reduces that of P_2O_5; on those poor in Mn the intake of P_2O_5 but not of Mn is increased. Mn intake on both fertilized and unfertilized soils increases and lime intake decreases with decreased lime content of the soil.

Němec, A. 373

1939 a Untersuchungen über den Einfluss chlorhaltiger Kalidüngemittel auf das Wachstum und auf die Ernährung der Fichte in Waldbaumschulen (Investigations on the effect of chloride-containing potassium fertilizers on the growth and on nutrition of Norway spruce in forest nurseries). Bodenk. u. PflErnähr. 13: 35-72. A

The effect of a one-sided fertilization with 40% potassium salt and Kainite on the growth of spruce in forest nurseries depends in

the first place on the potassium as well as the lime and phosphoric acid contents of the soil.

Potassium deficient are those soils, which contain less than 130 mg. K_2O, soluble in 1% citric acid, per kg. of soil. A one-sided potassium fertilization stimulates growth on potassium deficient soils containing more than 100 mg., in citric acid soluble P_2O_5 and more than 1500 mg. CaO, soluble in 10% NH_4Cl per kg. of soil. A one-sided K_2O application did not increase growth on lime deficient soils, in spite of insufficient potassium and a favorable P_2O_5 reserve. The unfavorable effect of the fertilization with 40% potassium salt and Kainite on the growth of spruce on lime deficient and strongly acid soils is believed to be the result of action of the chloride-ions in the potassium salts. Spruce has an aversion to chloride. Fertilization with chloride containing potassium salts on chloride rich soils had an adverse effect on the growth; on soils lacking chloride the results were in general favorable, in particular on potassium deficient soils with less than 130 mg. K_2O, soluble in 1% citric acid, per kg. of soil. The one-sided potassium fertilization on strongly acid soils, deficient in P_2O_5 was harmful in most cases, in spite of potassium deficiency. Spruce mortality, as a result of fertilization with potassium depends on the time interval between application and transplanting; the losses are considerably increased by lack of precipitation.

The fertilization with Kainite lead to far greater spruce losses than that with 40% potassium salt. The losses were quite small when the potassium was applied 4 to 6 weeks before the seedlings were transplanted. Kainite was quite destructive when applied before or at the time of transplanting or even after. Further, a detailed report is given on the effect of a one-sided potassium application on the nitrogen, potassium, lime, magnesium, manganese, iron and aluminum assimilation of the spruce needles under conditions of various degrees of soil reaction and soil nutrient content.

NĚMEC, A. 374

1939 b Untersuchungen über den Einfluss der Stickstoffdüngung auf das Wachstum der Fichte in Waldbaumschulen (Investigations relating to the effect of nitrogenous manuring on the growth of spruce in forest nurseries). Bodenk. u. PflErnähr. 16: 98-112. A

The effect of a one-sided nitrogen fertilization depends on the reaction and amount of available nutrients in the soil. The N-ferti-

lization stimulated growth of spruce on strongly acid, nitrogen-deficient soil with sufficient P_2O_5. On extremely acid soils fertilization had a noticeable stagnating effect on the growth; Chili nitrate had a more favorable action. One-sided N-fertilization on strongly acid and P_2O_5-deficient soils caused in most cases a decrease in growth. Application of the fertilizer shortly before or at the time of transplanting had an unfavorable effect on plant survival, especially when there was insufficient precipitation. As far as application of the fertilizer after transplanting was concerned, Chili nitrate did not favor plant survival; calcium nitrate and ammonium sulphate did not increase plant failure.

Chili- and sodium-nitrate must be applied at least three weeks before transplanting. Calcium nitrate and ammonium sulphate are also suitable for surface application, but not until three to four weeks after transplanting of the seedlings. An application with physiologic alkaline fertilization on strongly acid and physiologic acid fertilizers (ammonium sulphate) on neutral or weakly acid soil is in general the most favorable for plant survival.

NĚMEC, A. 375

1939 c (On the problem of alder nutrition on poor soils). Lesn. Práce 18: 26-35. (Czech w/German summary) A

Alder is a demanding species in respect to its nutrient requirement, especially as far as lime is concerned. It does not thrive on very nutrient-deficient and strongly acid soils. On a degraded soil (gley podzol with hardpan) planted with alder, fertilization experiments were conducted with limestone and artificial fertilizers (di-calcium phosphate.) Without fertilizers the alder grew very poorly, and most of it died. Growth stagnation can be traced back to disturbance in lime, magnesium, and phosphoric acid nutrition of the alder, as was proven by foliage analysis. Not until lime and fertilizers are applied will the normal nutrition of alder take place. A satisfactory growth is obtained especially after a mechanical destruction of the hardpan. This is a real contributing factor to the amelioration of the soil, in combination with the biological influence of the alder growth on the improvement of the "sick" soil.

NĚMEC, A. 376

1939 d (The influence of manuring with compost upon the growth of spruce in nurseries). Lesn. Práce 18: 148-156. (Czech w/German summary) A

A normal application of compost (30 kg. per 100 sq. meter) produced in the usual manner from plants remains, forest humus, soil and lime, represents only a minor amount of nutrients, corresponding to about 25 kg. Thomas slag and 25 kg. 40%-potassium salt per ha. The total amount of nitrogen from this application corresponds to about 60 kg. ammonium sulphate per ha; containing, however, only about 1.4 kg. per ha easily soluble nitrogen. The effect of a compost application (30 kg. per 100 m^2) on the growth of 3-year-old spruce was studied on soils with various reserves of nutrients. Increase in growth occurred only on high lime soils deficient in nitrogen. On soils with a medium content of lime the compost had a favorable effect, especially where those soils had insufficient phosphoric acid. No growth increase, or rather a reduction in growth, was observed on soils deficient in lime. In comparing the effect of compost with one-sided mineral nutrient applications, compost in general did not prove to be superior. In order to guard against eventual injuries and increased losses of spruce, the sensitivity of spruce for certain constituents of the fertilizers, must be considered especially when the fertilizers are applied to strongly acid soils. The manuring with compost in general does not create any danger in this respect. For soils with extreme conditions, for strongly acid and nutrient-deficient soils, supplementing the compost with mineral nutrients can serve as a remedy.

NĚMEC, A. 377

1939 e (Nutritional disturbances in stagnating spruce plantations on ortstein soils of the Weisswasser Estate in Bohemia). Lesn. Pracé 18: 397-412. (Czech w/German summary) A

Investigations were made of degraded sandy soil (podzol with hardpan) profiles (acidity, nutrient content, absorption capacity) in the (fine-textured) sandstone district of North Bohemia. The eluvial layers absorb the phosphoric acid to a very slight degree whereas this nutrient was almost completely fixed in the illuvial layers. Fertilization of spruce planted under pine, and of spruce on clear-cut areas, with artificial fertilizers (di-calcium phosphate, 40% potassium salt, calcium-nitrate) and with lime (dolomitic limestone) resulted only in a little growth increase, except in the case of the lime application.

Chemical analyses of the needles show that growth stagnation is caused by disturbances in the phosphoric acid and lime nutrition,

and also in the nitrogen nutrition of older plantations. The nutrient deficiency was eliminated by fertilizing, however the results of the lime application to the spruce under pine were insufficient, because the amounts of lime used were too small. The growth of a newly established plantation requires an abundant, continuous supply of effective fertilizer nutrients.

NĚMEC, A. 378

1939 f (The effect of a one-sided P_2O_5 fertilization on the nutrition of spruce plants in forest nurseries. VI. The effect on the uptake of iron and aluminum). Ann. Acad. tchécosl. Agric. 14: 33-46. (Czech w/German summary) Ba

Iron intake (Fe_2O_3) of spruce needles increased with decrease of P_2O_5 in the soil; it was slightly decreased with application of superphosphate and Thomas meal. Iron intake increased with increasing soil acidity. On soils deficient in P_2O_5, application of superphosphate resulted in increased height growth only when the needles contained less than 0.067% Fe_2O_3, and Thomas meal when the Fe_2O_3 content was below 0.10%. On acid soils Al_2O_3 content of needles was reduced by phosphate fertilizers, especially on the soils poorest in Al_2O_3; on neutral or weakly acid soils fertilizing, especially with superphosphate, resulted in greater Al_2O_3 intake where the soil had abundant Al_2O_3. Application of superphosphate led to increased growth of spruce only on soils poor in Al_2O_3 (less than 0.15% soluble in 1% citric acid) or where the needles contained less than 0.10% Al_2O_3. Thomas meal, on the other hand, increased height growth regardless of the Al_2O_3 content of soil or needles.

NĚMEC, A. 379

1939 g (The effect of a one-sided P_2O_5 fertilization on the nutrition of spruce plants in forest nurseries. VII. The effect on the uptake of silica). Ann. Acad. tchécosl. Agric. 14: 69-77. (Czech w/German summary) Ba

On untreated soils the SiO_2 content of the needles decreased as P_2O_5 content increased; application of phosphates led to a significant increase in SiO_2 intake only on soils deficient in P_2O_5. On soils rich in both P_2O_5 and SiO_2 fertilizing did not increase the

SiO_2 content of the needles, but on soils with less than 250 mg. SiO_2 per kg. there was a distinct increase. SiO_2 content of the needles increased and P_2O_5 content decreased with increase in soil acidity.

NĚMEC, A. 380

1939 h (The effect of a one-sided fertilization with potash and Kainite on the nutrition of spruce plants in forest nurseries. I. The effect on the uptake of potassium and phosphoric acid). Ann. Acad. tchécosl. Agric. 14: 270-277. (Czech w/German summary) Ba

The K intake of spruce needles generally depends on the supply of K in the soil. Application of 40% K_2O fertilizer on soil rich in P_2O_5 but poor in K_2O increased intake of K_2O of 3 year old spruce, especially on lime soils. Kainite was more effective on soils deficient in lime. Neither had much effect on soils deficient in P_2O_5. The P_2O_5 intake of the needles also depends on the quantity of P_2O_5 in the soil. Fertilizing with K_2O caused a moderate increase in P_2O_5 intake only on soils poorest in K_2O (less than 100 mg. per kg. of soil) and without much lime.

NĚMEC, A. 381

1939 i (The effect of a one-sided fertilization with potash and Kainite on the nutrition of spruce plants in forest nurseries. II. The effect on the uptake of nitrogen, calcium and magnesia). Ann. Acad. tchécosl. Agric. 14: 324-331. (Czech) w/German summary) Ba

The N intake of needles depends on the relative quantity of soluble N in the soil. Application of K stimulated N intake on soils with abundant N, especially those deficient in K, but both K and Kainite decreased N intake on soils deficient in N. Ca intake depends on quantity of exchangeable Ca compounds in the soil; addition of 40% K salt on soil poor in K increased Ca intake, but reduced it on soil with abundant K. On soil deficient in P_2O_5 results were similar except that Kainite was more effective than 40% K salt. On soil poor in both P_2O_5 and K, application of K reduced K_2O:CaO ratio in the needles. Mg. intake generally ran parallel with Mg content of the soil. Application of K increased it on soil with abundant P_2O_5 but lacking K.

Němec, A. 382

1939 j (Influence of unbalanced fertilizing with potash salts and kainite on the growth of spruce in forest nurseries). Ann. Acad. tchécosl. Agric. 14: 178-186. (Czech w/German summary) A

The effect depends in the first place on the potassium, lime and phosphoric acid supply of the soil. Potassium deficient soils contained less than 130 mg. K_2O per kg. of soil, soluble in 1% citric acid. The fertilization did not promote increased growth on lime-deficient soils, it rather was harmful to the growth, which can be traced back to the effect of the chloride-ion of the potassium salts. The fertilization was harmful on soils rich in chlorides. Injuries were caused on strongly acid soils, in spite of their potassium deficiency. The Kainite fertilization lead to far greater losses of spruce than the fertilization with 40% potassium salt. The losses of spruce increase with a shortening of the time interval between the application of the fertilizers and the transplanting of the spruce seedlings. Quite small losses were recorded with the application of the potassium-fertilizer 4-6 weeks before transplanting.

Němec, A. 383

1939 k (Nutritional disturbances of spruce plantations on ortstein soils of Hrubá Skalá Estate in Bohemia). Ann. Acad. tchécosl. Agric. 14: 239-250. (Czech w/German summary) Ba

Growth stagnation of spruce was evidently due to serious disturbance of lime and potash nutrition. Foliage and twigs of the stunted plants had a high content of SiO_2 and Mn. Liming stimulated growth, increased the intake of MgO and P_2O_5, and decreased that of SiO_2 and Mn. The best results were obtained by use of complete fertilizer (N-P-K-Ca-Mg).

Němec, A. 384

1939 l Die Störungen der Phosphorsäureernährung bei wachstumskümmernden Fichten-und Kiefernkulturen (Disturbances of the phosphoric acid nutrition of stagnating spruce and pine plantations). Phosphorsäure 8: 179-196. A

Reports on growth stagnation, disturbances of phosphoric acid nutrition of spruce and pine plantations as well as the results of

fertilization experiments on different soil types: (1) On podzols with ortstein in the (fine-textured) sandstone areas of the chalk formation. (2) On Neogen sandstone soils (gley-podzols with ortstein) of the South Bohemian tertiary. (3) On impoverished gneiss soils, and (4) on kaolinized gley soils of West Bohemia (Pilsen Basin.) In all these cases considerable disturbances of phosphoric acid nutrition of the plantations was found, which was caused by deterioration and "sickness" of the soil. Besides this, the excessive uptake of aluminum by the organs of assimilation and by the woody parts were found to be responsible for the growth stagnation on the kaolinized gley-soils. In most cases of stagnated and reduced growth, fertilization with Thomas slag had a very favorable effect on the growth and nutrition of the pine and spruce plantations.

NĚMEC, A. 385

1939 m (A new method for the improvement of degraded forest soils by means of basic rocks from quarries). Čsl. Les. 19: 160-162. (Czech) BaA

For the improvement of degraded forest soils in Czechoslovakia, which are strongly acid and deficient in nutrients, the application of crushed basic eruptive rocks, such as basalt, diabase, gabbro, melaphyre, and amphibolite, has been successful, especially in promoting a better growth of stunted forest cultures on podzol soils with hardpan layers. Diabase dust stimulated the growth of black alder, which was planted to improve the degraded soil. The growth of pine, larch, and oak also was greatly improved. On soil treated with diabase, basalt, or gabbro dust, the content of K and Ca in the foliage of the growing trees (pine, larch, alder, oak) and in the wood of their stems and roots was 2 or 3 times as great as in untreated plants. The dust of basic eruptive rocks was applied in the planting holes at the rate of 1-2 kg. per plant, or in the form of a diabase or basalt compost which had been prepared from forest weeds and acid humus material.

NĚMEC, A. 386

1939 n Über die Kompostdüngung der Fichte in Waldbaumschulen (Compost fertilizing of spruce in forest nurseries). Forstwiss. Zbl. 61: 406-421. fa

Fertilizer experiments in forest nurseries showed that the influence of compost on growth and nutrition of spruce seedlings de-

pends on the chemical composition of the soil, especially its acidity and its contents of soluble mineral salts. Best conditions of growth for spruce can be created by providing not only N, K, P and Ca, but also the other minerals that are lacking.

NĚMEC, A. 387

1940 a Über die Wirkung einer Stickstoffdüngung junger Fichten auf die Nährstoffaufnahme der Nadeln in Abhängigkeit von der Bodenreaktion und von dem Nährstoffhaushalt des Bodens (The effect of nitrogenous manuring of young spruce on the nutrient uptake of the needles in relation to soil reaction and nutrient content of the soil). Bodenk. u. PflErnähr. 17: 204-235. Ba

Analyses of needles of 3 year old spruces growing under varied conditions of stand in nurseries at 28 locations with soils varying widely in composition, the data thereon including pH, CaO and MgO soluble in 10% NH_4Cl and all constituents extracted by hot 10% HCl and cold 1% citric acid, and fertilized with N only in the carriers $NaNO_3$, $Ca(NO_3)_2$ or $(NH_4)_2SO_4$ are presented and discussed. Percentages in dry matter of needles are included for a total N, P_2O_5, K_2O, CaO, MgO, MnO, Fe_2O_3, Al_2O_3, and SiO_2, and for each the relations to supply in the soils and nature of fertilizer are discussed at length.

NĚMEC, A. 388

1940 b Ernährungsstörungen bei kümmernden Kulturen und Beständen (Nutritional disturbances of stunted plantations and stands). Mitt. Forstwirt. Forstwiss. 11: 244-266. A

A comprehensive paper dealing with the causes of growth stagnation of forest stands and plantations, on strongly acid, and nutrient deficient ortstein soils of the Quader Sandstone Region (chalk formation) and the tertiary sandstone in Bohemia, taking into consideration disturbances in the normal mineral nutrition of forest plants. The spruce plantations suffer mainly by lack of nitrogen, phosphorus and potassium, less by deficient lime nutrition. With the exception of nitrogen, the nutrient uptake of the needles depends on the nutrient content of the upper layers of the eluvial horizon. The content of the principal nutrients is increased to a

greater or less extent by a complete fertilizer, all depending on whether the soil is more or less deficient in nutrients. Application of a complete fertilizer resulted in a considerably increased nitrogen- and potassium-uptake of stagnated pine stand on tertiary sandstone, whereas common elder foliage showed a considerable increase in lime and phosphoric acid contents. Nitrogen uptake on the other hand had not changed, in spite of the deficiency of this mineral in the soil. Only after an adequate application of lime and fertilizers by which the acid reaction and deficiency in most important minerals of the leached soil layers are eliminated, conditions can be created for a successful reforestation.

Němec, A. 389

1940 c (The nutrition of spruce and pine underplantings on ortstein soils in the growth-stagnated pine stands of the forest district Cep near Wittingau). Lesn. Práce 19: 69-82 (Czech.) A

On the deteriorated soils (gley-podzol with ortstein) in the region of the famous Wittingau Pine in South Bohemia, serious growth stagnation of the pine stands is found. In the worst part of a dying pine stand, amelioration experiments were established, involving trench plowing and fertilization with lime, nitrogen, phosphoric acid and potassium, of pine and spruce underplantings.

The liming and fertilizer application had a favorable effect on the growth and in particular on the nutrition of the underplanted pine and spruce. Regarding nutrition, there was especially a serious decline in lime content of the needles as a result of soil deterioration. Lime- and potassium-content of the needles was considerably increased and silicic-acid and aluminum content decreased, by fertilization.

The deformed trees and stands showed in general an excessive disturbance in the lime nutrition. Without liming and fertilizing, which eliminate the nutritional disturbances, no successful reforestation of these soils can be expected.

Němec, A. 390

1940 d (The effect of a one-sided fertilization with potash and Kainite on the nutrition of spruce plants in forest nurseries. III. The effect on the uptake of manganese, iron,

aluminum, and silica). Ann. Acad. tchécosl. Agric. 15: 86-94. (Czech w/German summary) fa

Unbalanced fertilization with 40% potash salt or with Kainite markedly increases the Mn absorption of the needles on soils that are acid due to ion exchange, more so on soils poor in than on those rich in K_2O. The Fe absorption is also increased, likewise that of Al; in the latter case 40% potash salt had a stronger effect than Kainite, especiallly on soils rich in Al. On soils high in SiO_2 and poor in K_2O, unbalanced fertilization with K_2O considerably increases the SiO_2 absorption in the needles, but on soils rich in K_2O the SiO_2 content is generally not affected. On soils poor in SiO_2, the SiO_2 absorption is slightly increased by unbalanced fertilization with K_2O only when they contain less than 130 mg. of citric acid soluble K_2O per kg. soil.

Němec, A. 391

1940 e (Nutritional disturbances of deciduous trees on ortstein soils of the Hruba Scala estate). Ann. Acad. tchécosl. Agric. 15: 356-364. (Czech) A

Experiments involving fertilization of underplantings of beech, maple, and basswood in stagnated pine stands on the ortstein soils in the Quader sandstone region of the Forest District Troskovice in Northeast Bohemia with lime, potassium salts, di-calcium phosphate and calcium nitrate have shown good results. Within a period of five years all maple plants had perished on the unfertilized soil and only a small fraction of stagnated beech and basswood remained Lime and fertilizers limited mortality, in particular the beech and maple had luxurious foliage. However, growth was unsatisfactory.

Disturbance in potassium- and lime-nutrition in the beech underplanting was determined as the cause of the failure of the plantations. In addition, the phosphoric acid nutrition of the maple was much disturbed. An application of a complete fertilizer raised the potassium nutrition of the beech leaves, however, without attaining the contents normal for healthy plants. In the stems and roots the lime and magnesium contents in particular, increased, however, insufficiently. The lime contents of the maple remained far below normal after an application of a complete fertilizer; however, phosphoric acid assimilation increased. Liming of basswood caused a strong decrease of phosphoric acid- and aluminum assimilation by the stems and roots; the complete fertilizer gave a considerable increase of potassium assimilation. The failure of underplantings

of deciduous trees can in addition be caused by other factors, in particular biological capacity.

NĚMEC, A. 392

1941 a (The influence of fertilizing on the growth and nutrition of pedunculate oak in the forest tree nurseries of the Chlumetz Estate on the Cidlina). Ann. Acad. tchécosl. Agric. 16: 109-116. (Czech) A

In four forest nurseries fertilization experiments with one-year-old pedunculate oak were established. The soil content in easily soluble phosphoric acid and potassium were raised to 250 mg. and 160 mg. per kg. of soil respectively, as a result of the fertilization. The amount of lime applied corresponded to the requirement of the soil, as determined after Daikuhara. Phosphoric acid was applied in the form of di-calcium phosphate and potassium in the form of 40% potassium salt. Growth of the oak was in all cases more favorable when fertilized. Fertilization showed its best effect on strongly acid soils, where height increased to 30% and the total dry weight increase of tree volume amounted to 42% at the end of the 2nd year. On soils not deficient in lime, potassium fertilization affected total weight more than height growth of the plants, whereas, fertilization in combination with liming on acid soils affected more the stem development. Lime-free potassium phosphate fertilization was more of a root-developing stimulance on soils, not deficient in lime. Various degrees of soil fertility resulted in considerable differences in the mineral nutrition of the oak stems. Lime content increased noticeably with decreasing soil acidity and increasing reserve of exchangeable lime compound in the soil. On soils rich in lime, the highest dry matter weight was found with those oaks which had the highest lime content in the stems (3% CaO in the dry matter, or 53% CaO in the ash).

Also, the potassium content of the oak stems increases conspicuously with an increasing potassium reserve in the soil. The soils of the nurseries were in general quite deficient in potassium and the potassium uptake of the oak stems was relatively low. Fertilization effected a reasonable increase of the oak stems in lime on lime-deficient soils and an increase in potassium on potassium-deficient soils. The results of the experiments have proven that an application of fertilizers, on the basis of a soil analysis, is able to stimulate the mineral nutrition of plants and to increase the growth of English oak in forest nurseries.

1941 b (Increasing the fertility of degraded forest soils in the forest district Cep by fertilizers and lupine). Lesn. Práce 20: 30-39. (Czech w/German summary) A

An amelioration experiment was carried out on an ortstein podzol, supporting a stagnated pine and spruce plantation, heavily checked by heath. After the ortstein layer was mechanically broken up and mixed with the elluvial horizon, lime and fertilizers were applied (8 kg. ammonium-di-calcium phosphate, 1.5 kg. 40% potassium salt and 15 kg. dolomitic limestone per 100 sq m.). Perennial lupine did not grow on unfertilized soil, however developed well after an application of lime and fertilizers. Fertilization in combination with lupine had a very favorable effect on the growth of the pine and spruce plantations. After 3 to 4 years, following the fertilization and lupine seeding, height growth had increased 3 to 4 times in comparison to the control area. The nitrogen, lime, phosphorus, potassium- and magnesium content of the needles and wood of the spruce, in the plantations seeded in with lupine was considerably higher than of the spruce in the untreated plantations. Growth of lupine had at the same time favorably improved the physical properties of the soil. The soil remains moist, the evaporation of water is reduced; consequently there is more water available than in the heath checked and easily dessicated plantation on the control areas.

The application of lime and fertilizers, in combination with the growth of lupine on sandy ortstein podzols, mechanically cultivated, has proven to be a successful means for improving growth.

Němec, A. 394

1941 c Der Einfluss der Düngung auf das Wachstum der Fichten in der Waldbaumschule und auf ihre weitere Entwicklung nach dem Versetzen ins Freiland (The influence of fertilizing on the growth of Norway spruce in the forest nursery and upon further development after planting out). Bodenk. u. PflErnähr. 24: 113-128. A

A one-sided fertilization of 1-year-old spruce in a forest nursery, with various artificial fertilizers had a favorable effect on the growth. Nutrient content of the needles pointed to a distinct potassium deficiency, which was reduced by fertilization. After planting out on a clear-cut area, which, although rich in potassium, was

deficient in P_2O_5 and CaO, the spruce also showed a better growth. Only those plants, whose growth had been checked in the nursery bed as a result of unsuitable fertilization or in which the nutrient ratio in the needles had become more unfavorable, after fertilization showed less growth increase after transplanting than those spruce plants which had not been fertilized in the nursery beds. In a second experiment the effect was studied of a fertilization with increasing rates of P_2O_5 in combination with an NK application on a strongly acid and nutrient deficient soil. The effect of the added P_2O_5 on the growth of spruce became more favorable the greater the rate of application. When growth performance was good, the spruce treated with the complete fertilizer in the nursery, could manage with a less developed root system than the unfertilized plants or than the spruce treated only with NK fertilizer. The favorable effect of the P_2O_5 is distinctly reflected in the nutrient assimilation by the needles. After transplanting spruce on a clear-cut area, well supplied with nutrients, the growth differences which occurred on the nursery beds remain. Under these conditions there is a chance that a proper fertilization of the nursery beds will guarantee a more satisfactory growth of the trees in the forest.

NĚMEC, A. 395

1942 a (The causes of stagnation and means of improvement in the growth of Scots pine plantations in the forest district of Bělá near Hradec Králové). Ann. Acad. tchécosl. Agric. 17: 74-83. (Czech w/German summary. A

On the basis of soil and foliage analyses the causes were ascertained of the growth stagnation of pine in plantations with strong heath development, in an area which was clearcut 25 years ago. The sandy soil (of the cretaceous formation) is covered with various thick layers of diluvial sand. Except for a rather good phosphoric acid content, the upper, strongly acid soil layers are quite deficient in nutrients. The content of soluble aluminum compounds is rather high. A fertilization with moderate amounts of dolomitic limestone, di-calcium phosphate, potassium salt and ammonium sulphate, after the heath cover was removed, had a very favorable effect on the pine growth during the first 6 years. The lupine seeded on a part of the nitrogen fertilization area failed completely. Fertilization stimulated in particular the potassium uptake of the pine; on the other hand the rather high aluminum contents of the

needles was considerably reduced. The soil analyses, nutrient content of the plant organs and the results of the fertilization experiments clearly indicate that the growth stagnation of pine is caused by a disturbance of the potassium, lime and magnesia uptake as well as by the toxic effect of the aluminum in unfertilized soils.

NĚMEC, A. 396

1942 b Meliorationsversuche bei kümmernden Kulturen durch Düngung und Mitanbau der Dauerlupine (Experiments on the improvement of stagnating plantations by fertilizing in combination with cultivation of perennial lupine). Forstarchiv 18: 95-101. A

Stagnation of spruce and pine plantations resulting from strong heath development is occurring with increasing frequency. An amelioration experiment was carried out on a gley-podzol, strongly covered with heather. After the heath cover was removed the experimental area was fertilized (150 kg. dolomitic limestone and 5 kg. Thomas slag per 100 sq. m.) and planted to lupine. These measures had a very favorable effect on the growth of the pine. The physiological causes of this effect are based on an increased lime and phosphoric acid uptake by the pine in wood and needles, as a result of fertilization as well as on a considerable decrease of successive aluminum uptake, which leads to toxicity in stagnated plantations. The increase of nitrogen and magnesia contents of the pine needles is quite striking; no such increase is shown in the content of the wood. This may be correlated with the increased chlorophyl formation of the fertilized pine. The needles of the stagnated pine on the unfertilized area have an unhealthy, yellow-green color.

A second experiment was carried out on degraded sandy soils (ortstein podzol and gley podzol) with a similar fertilization (15 kg. dolomitic limestone, 8 kg. ammonium-di-calcium phosphate and 1.5 kg. 40% potassium salt) and lupine cultivation. The lupine failed completely on the unfertilized soil as in other experiments mentioned before. The effect of the fertilizers and lupine on the growth of spruce and pine was quite favorable. The nitrogen uptake and the phosphoric acid, lime, potassium and magnesium content of the thrifty fertilized spruce had increased considerably as a result of the lupine cultivation. The silicic-acid, aluminum and manganese content on the other hand had decreased distinctly. Fertilization in combination with lupine cultivation therefore promises good success in the control of growth stagnation of pine

and spruce on strongly acid, degraded and heath-covered forest soils.

NĚMEC, A. 397

1943 a (The influence of fertilizing and of perennial lupine on the properties of degraded forest soils). Ann. Acad. tchécosl. Agric. 18: 175-187. (Czech w/German summary) A

Reports on the effect of liming, fertilizing and lupine cultivation on the properties of a degraded sandy soil (podzol with ortstein). In 1926 the soil was mechanically cultivated in order to break up the hardpan. The A and B horizons were mixed and fertilized with limestone dust, ammonium sulphate and potassium salt. The mentioned treatments influenced the growth of the pine, spruce, and alder quite favorably. On the unfertilized control area, however, where after removal of the heath the soil was only mechanically cultivated, pine and spruce stagnated in growth and the alder was completely killed. The morphological properties of the soil showed fundamental differences. The unfertilized, mechanically cultivated area had again developed a podzol profile with hardpan under a new heath cover, formed during the past fifteen years. On the other hand, the profile of the fertilized area, which is covered with dense and luxurious heath growth shows the morphological characteristics of a helathy brown forest soil, with favorable reaction and nutrient conditions. The effect of the lupine cover was not only manifested by a maintenance of soil moisture but also by an increase in humus, nitrogen, and availability of nutrients, as a result of the activity of the lupine roots.

The results of the experiment justify the conclusion that, under the given site conditions, the measures taken brought about in the first place beneficial changes in the chemical properties of the soil, which in turn favored a normal nutrition of the tree species.

NĚMEC, A. 398

1943 b (The types of forest soils). 170 pp. Novina, Prague. (Czech) Ba

The book contains a comprehensive discussion of the origin, properties, and silvicultural importance of various forest soil types in Bohemia. Detailed profile descriptions are given for podzols, podzolic soils, brownearths, rendzinas, blackearths, gley soils, and limonitic soils in different parts of Bohemia. The descriptions are supplemented by the writer's physical and chemical analyses. The

silvicultural characteristics of each soil type include a list of species suitable for reforestation. Special attention is given to forest soils of low productivity (podzols with hardpan horizons, poorly drained gley soils, and Kaolinic soils) and to their amelioration by mechanical, chemical, and biological means.

NĚMEC, A. 399

1945 (The use of basalt dust to improve the growth of plants in forest nurseries). Čsl. Les. 25: 49-51. (Czech) BaA

On strong acid podzolic sandy soils of forest nurseries, showing a great deficiency of nutrients and containing raw-humus particles, pulverized and crushed basic eruptive rock from basalt, diabase, and melaphyre quarries in Bohemia was used to improve the nursery stock and to make possible the growth of certain hardwoods with a high mineral nutrient requirement (*Tilia*, *Fraxinus*). The basalt rocks of quarries in north and northeast Bohemia contain about 10-12% CaO, 9-14% MgO, and 1.5% K_2O; the melaphyre rocks 9% CaO, 6% MgO, and 1.8% K_2O; and the diabase rocks 10-11% CaO, 7.5% MgO, and 1.4-2.4% K_2O, in form of basic silicates. The SiO_2 content ranges between 40 and 48%. The basalt was applied to the nursery beds at the rate of 167, 83, and 41 kg. per 5 sq. m. of surface, i.e. a layer 2, 1, and ½ cm. The effect of basalt upon the growth of *Tilia parvifolia* and *Pinus silvestris* seedlings was remarkable in the number of surviving plants and their height and rate of development. On untreated beds the lime trees failed completely, while the use of basalt allowed a normal growth. The best effect was obtained with 83 kg. basalt per 5 sq. m. (a layer of 1 cm.) Experiments in the same nursery with pine seedlings showed also a significant increase in height growth; the average increase was 28-220% in favor of fertilized stock. Pulverized basic rock such as basalt, melaphyre, diorite, gabbro, and phonolite may well be used in the preparation of composted fertilizers.

NĚMEC, A. 400

1946 (Improvement of degraded impoverished forest soils with basic igneous rock dusts). Čsl. Les. 26: 280-284. (Czech) A

In order to improve a degraded sandy soil (hardpan podzol) in North Bohemia, a fertilization experiment was carried out with basalt dust, a waste product of stone quarries. The basalt dust contained 11.4% CaO, 14.6% MgO, 1.7% K_2O and 1.1% P_2O_5. The

basalt dust was applied to a spruce underplanting in a pine stand in a layer of about 2 cm. thickness. The dust was not mixed with the soil or humus layer. At the same time, perennial lupine was seeded in, which only survived on the fertilized area. The increase in height growth of the spruce is quite distinct four years after the experiment was started. Far better results were obtained with the basalt dust application where group cuttings were made in spruce plantations. An experiment was also made with diabase dust of similar composition, to improve growth-stagnated plantations. This material was applied in a layer of about 1 to 2 cm. thickness after weeds, such as heath, whortleberry, etc., were removed.

NĚMEC, A. 401

1948 a (The significance of trace elements for the growth of forest plants). Lesn. Práce 27: 117-130. (Czech w/English summary) faA

Reviews literature, with special reference to Mn, Cu, and B, and briefly describes experiments in Czechoslovakia with the two latter.

(1) In 1934, in a checked Norway spruce plantation on a degraded sandy podzol with hardpan, the heather was removed, the soil loosened and copper slag (1.62% CuO) applied at 12 kg./100 sq. m. In 1946 the heights of the treated and untreated plots were respectively 11.8 and 94.4 cm.), the foliage of the former being green and that of the latter yellow-green.

(2) In 1940, a deep, clayey, somewhat acid nursery soil (pH 5.92), poor in N, P, and K, was treated with ground limestone alone (2 kg./5 sq. m.) or the same plus borax (25 g. borax, or 2.87 g. B/5 sq. m.). Norway spruce 1-0 stock was put in 14 days later. Both treatments improved development and foliage color of the transplants, the combined Ca/B treatment giving the better results. This was confirmed by the fresh weights of the transplants in mid-April 1943. For controls, Ca and Ca/B treated plots (in that order and in decagrams per 100 plants), these were: shoots—240, 232, 287; roots —87, 99, 172; total—327, 331, 459.

NĚMEC, A. 402

1948 b (Fertilization of forest cultures. I. Use of fertilizers in forest nurseries). 218 pp. Brázda, Prague. (Czech) BaA

This book gives an account of experiences with the use of fertilizers in forest nurseries and summarizes the results of the author's

20 years work in this field. The introductory part, dealing with selection of nursery sites and principles of nursery management, is followed by a discussion of nutrient requirements of seedlings, intake of nutrients during various periods of growth, and symptoms of malnutrition. Special attention is given to the role of micro-nutrient elements and mycorrhizal fungi. Soil enriching materials are treated under 5 headings: organic fertilizers (humus, peat, compost, liquid humate, and animal manure), green manure crops; mineral fertilizers (ash and lime, N, P, and K fertilizers); crushed rocks (basic eruptive rocks: basalt, diabase, gabbro, etc.); and industrial waste by-products. Attention is given also to the collection of soil samples, diagnosis of nutrient deficiencies by chemical analysis of green plants, and the maintenance of fertility guided by soil analysis. Remarkable results were obtained with the combined use of commercial fertilizers and legume crops (green manure) as well as with the application of crushed diabase, basalt, and gabbro. The best results from manuring with crushed basalt were obtained on highly acidified and impoverished, degraded glei and podzol soils. The last chapter deals with the behavior of fertilizer treated stock under field conditions The literature contains one of the most complete lists of references of American and international work in this field published to date.

Němec, A. 403

1949 a (Research experiences relating to the growth improvement of stagnated plantations and to the amelioration of degraded forest soils). Čsl. Les. 29: 22. (Czech) A

Gives a short discussion on the nature of forest soil degradation, its causes and consequences, as well as on the measures to be taken to restore the fertility of the soil. In particular the importance of the chemical analysis of the soil profile is emphasized, which is the basis for the determination of the method to be used for improving soil conditions. Fertilization with basic igneous rock dust, in particular of diabase, melaphyre, spilite gabbro, gabbro-diorite, amphibolite and other similar rocks, has proven to be best for the amelioration of deteriorated forest soils. According to experience, underplantings cannot be successfully established on deteriorated soils, not even with a simultaneous application of fertilizers, because the root competition of the older stand has a considerably unfavorable effect on the development of the young trees, the dropping needles

will increase the acidity again so that improvement of the soil is out of the question and degradation sets in again. Cuttings practices, such a group cutting and clearcutting of small patches proved to be more successful; the root competition of the old stands and their unfavorable influence on the soil were removed. The best way to apply the rock flour is in the plant holes or on the seedbed (oak) where by larger amounts or rock dust can be used (2 to 3 kg. per plant hole). In addition, rock dust can also be applied after planting, provided the material is thoroughly mixed with the humus and mineral soil. For amelioration of the biological conditions of the soil common alder and hazel (*Corylus avellana*), with a simultaneous application of fertilizer proved to be very beneficial.

NĚMEC, A. 404

1949 b (Use of basic igneous rocks for the improvement of degraded forest soils). Zpr. výzkum. Úst. lesn. ČSR 1949: 32-74. (Czech w/Russian and English summaries) A

Ground basic igneous rocks, in particular basalt and diabase can be used with good success as fertilizer material for the improvement of degraded, strongly acid and nutrient deficient soils. These types of rock, obtained from various stone quarries in Bohemia, contained the following amounts of nutrients: basalt 8.3-13.2% CaO, 3.4-14.6% MgO, 0.6-2.2% K_2O and 0.6-1.2% P_2O_5, diabase: 8.8-11.1% CaO, 7.5-8.7% MgO, 1.4-2.3% K_2O and 0.3-0.8% P_2O_5. In addition, other basic rocks can be used such as spilite, melaphyre, gabbro, gabbro-diorite which contain much calcium and magnesium as well as potassium and phosphor. A study was made of the effect of a basalt application on coniferous and deciduous tree species in forest nurseries. The application of a 0.5-2 cm. thick layer of basalt dust resulted in a decided growth increase of basswood plants on a degraded sandy soil. The lime and potassium contents of the leaves had considerably increased. The fertilization had also worked very well on other forest species (pine, ash). The basalt and diabase fertilizers were also applied with good success, to improve the growth of stagnated common elder, pedunculate oak, larch, pine and spruce on impoverished and acid sandy soils. After removal of lower vegetation, (heath, moss, whortleberry) the fertilizers were applied in a layer of about 1 to 2 cm. thick or placed in the plant hole (1-2 kg. basalt or diabase). Common alder reacted most favorably after fertilization by increase in growth and greater nutrient

content of foliage, in particular lime and potassium. The application of the fertilizers in the plant holes showed in general better results than the surface application.

NĚMEC, A. 405

1950 a (Improvement of the degraded forest soil in the Choltice forest range by means of diabase rock dust). Ann. Acad. tchécosl. Agric. 25: 55-64. (Czech w/Russian and English summaries) A

The cause of growth stagnation of pine stands and forest plantations is the serious depletion of lime, magnesia, potassium and phosphor in the soil horizon, nutrients which are displaced to a depth of 50-70 cm. as a result of acidification of the humus cover. The azonal profile consists of sandy loam which at a depth of 70 cm. changes into sandy clay loam (Elbe deposits). In order to improve the growth of forest plantations, fertilization experiments were carried out with diabase rock dust. In the first two years after application of a 1 to 2 cm. layer of diabase dust, red oak and basswood showed already a definite growth increase. Application of the diabase dust to the plant holes (2 kg. for each plant) proved to be less successful, where the material was deposited on the bottom of the planthole, without being mixed with the soil.

The fertilization resulted in a distinct increase in nutrient content of the foliage, in particular in lime, magnesium, potassium and phosphorus. A distinctive increase of nutrient content of oak leaves and larch needles was found a number of years after the diabase dust was applied, which proves the lasting influence of the fertilization on the growth and the nutrition of the forests.

NĚMEC, A. 406

1950 b (Raising aspen from seed). Pol'ana 6: 267-269 (Czech) fa

The author raised ca. 50,000 aspen plants from seed in 1950, an imposing number in view of the high susceptibility of the seedlings to injuries. Five different methods of soil preparation, sowing, and tending, are described. The most important single factor is soil moisture. Best results were obtained with the following method. The experimental plot was well manured in the autumn with stable manure mixed with ashes, using a layer of manure 6 cm. thick, and loosening the soil to a depth of 25 cm. Six days later, a 3 cm. layer of ashes was spread on the soil, and thoroughly mixed with clay,

using iron rakes. Next May, the plot was weeded, and seeds collected on 2 May were sown on the 29th in furrows 4 cm. wide and 1 cm. deep. The plant % was 71. After sowing, the beds were thoroughly watered. Eight hours later the green of the leaves was already perceptible, and after 28 days the aspen growth became so thick as to necessitate thinning. The plot was watered every morning, care being taken to use a very fine spray. During growth, the seedlings were 6 times sprayed with $CaSO_4$ solution. Thirty days after sowing, the seedlings were 3.5-5.5 cm. high and the roots well developed, their length being 7-13 cm. Forty-five days after sowing the plants were 4-19 cm. high with very extensive root systems. The last watering was done on 10 July.

NĚMEC, A. 407

1950 c (The fertilization of forest plantations. Amelioration of stagnated plantations and stands). Rec. Inst. Rech. agron. Rep. tchécosl. 3. 437 pp. (Czech w/Russian and English summaries) A

The first part of this monograph summarizes the research to date, in Czechoslovakia and elsewhere, on the use of mineral fertilizers, peat or raw humus, mulching with plant residues and growing leguminous plants such as perennial lupine or broom, (in combination with mineral fertilizers) and auxiliary soil-improving species, to improve degraded soils under Scots pine (pp. 6-74), Norway spruce (pp. 75-113), other conifers viz. *Abies alba*, *Larix decidua*, *Pinus nigra*, *Pinus strobus*, *Pinus banksiana*, *Pseudotsuga taxifolia* and *Picea sitchensis* (pp. 114-138) and hardwoods viz. beech, oaks, *Quercus robur* and *Quercus borealis*, ash, elm, lime and birch (pp. 138-164).

The second part deals with the results of trials made by the Institute of Bio-chemistry and Pedology, Prague, in order to determine the most suitable methods of fertilizing plantations on different types of degraded forest soils, viz. azonal soils, (pp. 166-200) podzolized brown forest soils and podzols (pp. 200-221), podzols with hardpan (pp. 221-299) and gley soils (pp. 300-396). The results of the various treatments obtained on the principal soil types are as follows:

1. Fertilization with lime and artificial fertilizers: Azonal soils. Under-plantings of hardwood species in old pine stands on highly impoverished and acid soils failed completely in spite of liming

and an application of phosphate and potassium fertilizers. Root competition, continued acidification of the soil as a result of the pine needle cover and insufficient fertility were considered causes of this failure. Liming and the application of artificial fertilizers (including basic rock dusts) had a favorable effect on the growth of plantations on open fields and on clear-cut patches in the old stand. The more deficient the soil was in nutrients the better the effect of the fertilizers. The nutrition of the forest trees had greatly improved and the toxic effect of manganese and aluminum uptake on highly acid and impoverished soils had been eliminated as a result of the fertilization.

Podzolized brown forest soils and podzols: The best results of the fertilizing were observed on the poorest and most acid soils. Liming reduced acidity to a pH (KCl) of 4.5-5.0 and the application of fertilizers increased the P_2O_5 and K_2O contents (soluble in 1% citric acid) to 90-100 mg. and 70-80 mg. respectively per 1000 grams of soil. Pine, larch, black alder and large-leaved basswood responded best to the fertilization. The effect on spruce was relatively small. The most significant improvement of nutrient absorption was observed on the poorest and most acid soils. The toxic effect of aluminum absorption on the podzols was eliminated by fertilization.

Podzols with hardpan: Underplantings of hardwood and softwood species in pine stands failed in spite of repeated liming and fertilizing with phosphate and potassium. The more demanding hardwood species died completely. The causes of this failure were considered to be lack of nutrients, soil acidity, root competition and the presence of hardpan layers. On open fields, clear-cut patches and in heavily thinned stands the treatments were more effective in improving the growth of the plantations, in particular when in addition to fertilization the soil was mechanically cultivated. Absorption of calcium and phosphorus (especially pine and black alder) had greatly improved. Absorption of toxic aluminum compounds was eliminated or reduced to a considerable degree.

Gley soils: Liming and fertilization stimulated the growth of pine plantations. The results with spruce were less favorable on the very acid and extremely lime- and phosphoric acid-deficient soils. However, spruce is not suitable for the reforestation of gley soils because the superficial root system of this species has no access to the moisture and nutrients of the deeper soil layers. Black alder and oak responded very favorably to the liming and fertilizing. Without fertilization, black alder, oak and basswood failed on degraded soils.

Under-plantings of alder in old pine stands did well if large amounts of lime and fertilizers were applied and the over-story was heavily thinned. Liming and fertilizing improved the nutrient uptake of the forest plantation to a considerable extent. The calcium content of spruce and pine needles increased to 0.9-1.1% CaO in the dry substance. On poor soils the potassium contents of the needles increased sharply. Liming on unfertilized and degraded soils decreased the absorption of phosphoric acid. Hardwood leaves showed a considerable increase of calcium content. Liming and fertilizing of degraded gley soils reduced the absorption of manganese and aluminum in the assimilating organs of the forest trees, thereby eliminating the toxic effect of these substances, which is one of the causes of stagnation or failure of growth.

Liming and fertilizing in combination with perennial lupine cultivation: Lupine does not succeed on poor and acid soils. Lupine cultivation is possible by liming and fertilizing providing the acidity is reduced to pH (KCl) of 5.0. Lupine can therefore be used as an indicator of soil fertility. On fertile soils a dense cover of lupine is not recommended because of danger of suppressing the forest plants(especially pine). Perennial lupine cultivation in combination with fertilizers caused a considerable growth increase of forest plants. Larch responded best; pine, however, less. On degraded azonal soils and on podzols fertilization in combination with the cultivation of perennial lupine had a favorable effect on the growth of hardwoods, in particular beech, large-leaved basswood and black alder. Liming alone cannot ensure the amelioration of growth even when it makes successful lupine cultivation possible. As a result of lupine cultivation the nitrogen nutrition of the forest plantations had considerably improved. Pine and spruce needles showed an increase of 50% and alder leaves an increase of 10% in nitrogen content.

Fertilization with basic rock dusts: Basic igneous rocks (basalt, diabase, melaphyre, spilite, gabbro, gabbro-diorite, amphibolite) contain besides other nutrients, lime, magnesia and potassium bound in the form of silicates and are marked by their capacity to form in combination with the acid raw humus of degraded forest soils, humo-silicates which are the basic constituent of the nutritious humus of productive forest soils. Lime and artificial fertilizers do not possess this property. Fertilization of impoverished azonal soils, podzols, ortstein podzols and gley soils with crushed basalt, diabase and gabbro increased the growth of forest plantations to a consider-

able extent and made possible the growth of hardwood species which formerly failed. Growth of black alder, broad-leaved basswood, pine and larch had doubled or tripled compared to the stunted unfertilized stands. Basic rock dust stimulated in particular the growth of species with deep-growing root systems. As a result of fertilization the roots are able to penetrate the leached A horizons and to reach the enriched B horizon. Chemical analysis of the soil profile showed that the decomposition products of the basic igneous rock dusts gradually leach to a considerable depth, thereby causing a softening and progressive decomposition of the hardpan layer. At the same time the harmful high acidity is changed to one that is more near the optimum of pH (KCl) 5.0. The lime, potassium and phosphorus content of the foliage and the stems of the forest plants were doubled or even tripled following fertilization with basic rock dusts. Only nitrogen remained at a minimum so that the most favorable effect of basic rock dust fertilization may be expected with those species which are able to utilize air nitrogen or when the treatment is combined with the cultivation of lupine. Adding basic rock dust to the planting holes is more effective than a surface application. The closer the root system is in contact with the dust, the better and quicker the result that can be expected. Underplantings in pine stands, fertilized with basic rock dusts failed completely. Where the rock dust was applied to plantations on open fields or on clear-cut patches, favorable results were obtained.

NĚMEC, A. 408

1952 a (Amelioration of an ortstein podzol in the Žehrov forest district by fertilizing with basalt dust). Ann. Acad. tchécosl. Agric. 25: 83-96. (Czech w/Russian and English summaries) A

Amelioration experiments were carried out on a degraded sandy soil (ortstein podzol, a weathering product of Quader sandstone of the Cretaceous formation) by fertilizing deciduous tree species with basalt dust and limestone. Amounts of 1 kg. basalt dust with or without 1 kg. of limestone were either added in the planting holes or applied round the plant after planting. Also an experiment was made by adding the basalt dust to the planting holes in combination with a surface application of limestone after the weed growth was removed. Common alder and oak reacted more favorably to the surface application of the fertilizer, and also did an underplanting of beech. In general the best responses were obtained from an

application of basalt and limestone in the plantholes on the clearcut areas. The least result was obtained from the surface application of basalt dust. Considerable differences in height increase occurred three years after fertilization. Nitrogen and lime contents of the alder foliage had considerably increased as a result of the basalt and basalt + limestone fertilizations. The basalt increases the phosphor contents of the leaves, whereas on the contrary, lime impedes the uptake of phosphoric acid. A soil analysis showed that a minimum of 2 kg. of basalt dust is needed to improve the growth of deciduous species. This was confirmed by experiments with alder and hornbeam, which showed significant growth increase in the second year after an increased application of basalt. Basswood also responded in the same way in the third year. Plant losses are always most considerable on the unfertilized areas, the basalt fertilization strongly reduces or eliminates the mortality entirely. Adding lime in the plant holes increases plant losses. Maple spp. and elm spp. failed to respond to the fertilization.

NĚMEC, A. 409

1952 b (Use of "Kapucin" (soft lignite) for fertilizing forest plants). Ann. Acad. tchécosl. Agric. 25: 97-104. (Czech w/Russian and English summaries) A

Kapuzin, (lignite), a waste product of the brown coal mines in North Bohemia can be used as fertilizer on humus deficient soils. Besides a considerable amount of humic acid (over 70%) it contains relatively many mineral substances, predominantly silicic acid. The total mineral nutrient content is quite low (0.2-0.5% CaO, 0.2-0.6% MgO, 0.15-0.30% K_2O, 0.25-0.40% P_2O_5 in kapuzin samples of 15% or less ash content). Trace elements present are Cu, Cr, Ba, Zr and in larger amounts Ti, V, and Mo. Of particular interest is the molybdenum content (0.01-0.02% MoO_3). Sulphide content is low (0.005-0.008% S). In comparison to brown coal, kapuzin is quite acid. The pH (H_2O) in the hydro suspension can be as low as 3.00 and the pH (KCl) in KCl solution can be as low as 2.3. The strong acidity, high reduction capacity of the kapuzin and the presence of certain groups of organic substances (stearine, montan wax etc.) makes this material unsuitable for direct application as fertilizer. It is recommended to neutralize the acidity of the kapuzin with basic rock dusts, in particular with those having a pH(H_2O) of 8.5 to 8.9. With sufficient moisture the opposing reaction of both components of the mixture causes the formation of substances which closely

resemble the nutrient humus of the fertile soils and which contain complex humic silicates. In order to reduce the acidity of the kapuzin to a pH(KCl) of 6.0 it is necessary to mix it with diabase rock dust in the ratio (by weight) of 1 part kapuzin to 3 or 4 parts of diabase dust. The important mineral nutrients are supplied by the diabase dust where as the nitrogen comes from the kapuzin (0.8-1.4%N). The results of the use of this organic-mineral mixture as fertilizer in forests is discussed in a separate paper.

NĚMEC, A. 410

1953 a (The effect of fertilizing on the degraded soils of the forest district Lovčice in Bohemia) Práce vyzkum. Úst. lesn. ČSR 3: 149-181. (Czech w/English and Russian summaries) A

In the forest district Lovčice the profiles of gneiss soils show a typical deterioration: strong acidification and leaching of the principal nutrients Ca, Mg. K and P. In practice the fertilization with wood ash and artificial fertilizers (Thomas slag and kainite) made natural regeneration of tree species possible and stimulated the growth of the forest. The greatest response was obtained in the third year after fertilizer was applied. A few years after fertilizing, it was found that Ca and P content of the upper soil layers, to a depth of 15 cm. had increased. The PK-fertilizer caused distinctive and favorable changes in the humus, and in particular slowed down the decomposition of the organic material. In spite of the application of PK fertilizer, the beech under planting in a pine-spruce stand led to a moderate acidification of the soil (the necessary liming was omitted) and the early-growing beech exhausted to a certain extent the soil reserves of easily soluble nutrients. The least increases in nutrient content as a result of fertilization showed up in the extremely poor soils of the pine stand, which on account of its great permeability made leaching of the added nutrients possible. Moreover, the phosphoric acid of the fertilizer was changed into a less available form through the effect of easily soluble aluminum compounds in the soil.

NĚMEC, A. 411

1953 b (Guide to the improvement of degraded forest soils: Instructions on the use of basic rock dusts for the amelioration of growth-stagnated plantations and stands on de-

graded and impoverished soils). Lesnická knihovna (malá řada) 28: 31 pp. Státní Zěmědelské nakladatelství, Praha. (Czech) A

A practical guide on the use of basic rock dusts for the amelioration of degraded and impoverished forest soils, based on the author's long years of research. In the introduction a detailed description is given of the main types of degraded forest soils: podzols, podzols with ortstein, degraded rendzina soils, soils affected by ground water (mottled soils, gley soils, gley podzols). The amelioration of degraded forest soils, in particular of podzols with ortstein, is further discussed. As a preliminary the chemical analysis of the soil is described, and the soil sampling for the determination of the minimum size of the basic rock dust application (evaluation of the soil analysis). After this instructions follow for the practical application of rock dust, mechanical cultivation of the soil, preparation of organic-mineral compost from forest humus, weeds, Kapuzin (soft lignite) and basic rock dust. In addition, some remedial measures are described, such as the covering of soil with heather mulch, brush, etc. Some of the experiences are reported regarding the choice of timber species for degraded and impoverished soils, including the choice of soil improving species and plants (perennial lupine). The last section deals with the ways and means of changing pure forests into mixed forests, as well as with the results of amelioration work on impoverished forest soils in Czechoslovakia.

Němec, A. 412

1954 a (The amelioration of impoverished forest soils). Lesn. Práce 33: 442-449. (Czech) A

In the interest of the preservation of forest stands much attention must be given in the future to the degradation and impoverishment of forest soils. Timely and thorough measures must be taken to effect a recovery of the endangered forest regions. Moreover, a further deterioration must be prevented and these soils must be excluded from normal timber harvesting. Podzolization has not only caused a serious depletion of the principal nutrients(Ca, Mg, K, P) in the A-horizon, but has also leached the vital trace elements from the upper soil layers to the enriched B horizon. As a result the young trees suffer from a catastrophic nutrient- and trace element-deficiency with a subsequent stagnation or complete failure of growth. The decomposition of humus in the degraded soils is seri-

ously disturbed, causing nitrogen deficiency. Only liming and fertilizing can restore the fertility of those degraded and impoverished forest soils. Numerous experiments have shown that in most cases liming alone does not give satisfactory results. However, afforestation of impoverished forest soils will be most successful when they are fertilized with certain basic rock dusts (basalt, diabase, spilite, andesite, gabbro, melaphyre, amphibolite, etc.) with or without lime or mixed with organic matter (raw humus). For example, the results are cited of an amelioration experiment on a poor sandy soil, (Elbe deposits) near Doksany in Bohemia. As a result of intensive litter removal in former years, the soil was seriously depleted of organic matter, nitrogen and mineral nutrients. For the purpose of ameliorating the soil conditions, three different kinds of compost were applied, consisting of raw humus, removed from the growth-stagnated pine plantation, (1) mixed with quicklime, (2) mixed with basalt dust and (3) mixed with quick lime and basalt dust. These materials were left to decompose for three years. Quantities of 3 kg. compost (about 10 cub. dm.) per one square meter were used.

The three treatments were further combined with a cultivation of perennial lupine (*Lupinus perennis*). The basalt dust- raw humus-compost in combination with lupine cultivation proved to be best; plant failure was reduced to a minimum or even totally stopped, and the height growth of sycamore maple (*Acer pseudoplatanus*) and oak increased more than three times and of basswood more than twice. The alder completely failed on the unfertilized areas. The compost can also be successfully added to the plantholes or applied to the seedbeds.

Němec, A. 413

1954 b (The improvement of stunted forest stands on ortstein podzols by covering the soil with heather and fertilizing with a basic rock). Práce výzkum. Úst. lesn. ČSR 4: 5-34. (Czech w/English and Russian summaries) A

Covering the soil with a heather mulch had a very favorable effect on the growth of spruce on the degraded sandy soils (ortstein podzol) derived from the limestone formation in North Bohemia. The experiment was carried out on a clearcut area from which the heather had been removed a number of years ago. The changes of the chemical properties of the soil profile resulting from the mulching with heather are described (increase in acidity, increase

of organic matter and nitrogen and changes in nutrient content). The use of the heather mulch on the heath overgrown soil surface resulted in the maintenance of soil moisture, in particular in the Ao and the A horizons. The cover further effected an increase of the nitrogen, potassium and phosphoric acid contents of the spruce needles with a simultaneous decrease of calcium and magnesium content. A basalt dust application alone on this nitrogen, humus and nutrient-deficient soil did not stimulate the growth of spruce as well as did the heather mulch; however it had a favorable effect on the chemical properties of the soil (decrease of acidity, increase of nutrient content with the exception of nitrogen and an increase of trace elements) and on the nutrient content of the spruce needles. The basalt dust also had a favorable effect on the soil moisture conditions, but less than the heather mulch. Fertilizing with basalt dust stimulated the growth and nutrition of the spruce. A combination of the two treatments, viz., basalt dust and heather mulch, is recommended on dry, humus and nutrient-deficient, acid sandy soils. The basalt increases the content of important trace elements in the soil, such as Cu, Cr, Zn, Co and Ni, which are either completely or partially lacking in degraded sandy soils. The Cu content is of particular importance in heath-overgrown soils because it seems that this element is absolutely necessary for the normal development of the forest. The heather mulched soil had a higher Cu content than the unfertilized and unmulched soil, despite the heath development. The Cu-uptake of the spruce needles was increased by both the mulch cover and the basalt dust application.

Similar results were obtained with common alder, which showed an increased growth when the soil was covered with heather mulch and fertilized with diabase dust. Within a period of three years the height of the fertilized and mulched alder was three times as high, and twice as high when treated with diabase alone, than the unfertilized and unmulched alder on heath overgrown soil. Moreover, the mortality of alder was considerably decreased. The diabase fertilizing in combination with the heather mulch caused a considerable increase of the phosphor and magnesium uptake by an increase of the nitrogen content of the alder foliage. The fertilizing in combination with mulching moderately reduced the acidity of the Ao, A and B-horizons and prevented moisture losses by evaporation from the upper soil layers. This combination of amelioration treatment enables the afforestation of humus and nitrogen-deficient podzolized sandy soils not only with coniferous species, but also

with deciduous trees, where a basalt application alone is not sufficient to effect a favorable growth increase.

NĚMEC, A. 414

1954 c (Growth stagnation and failure of forest plantations on serpentine soils as a result of nickel, cobalt and chrominum poisoning). Práce výzkum. Úst. lesn. ČSR 6: 5-54. (Czech) A

Soils formed from the weathering of serpentine are characterized by considerable chromium, nickle, cobalt and copper contents. The growth stagnation of plantations on these soils is not due to the acidity or nutrient deficiency of the soil, but the high magnesium contents as compared to the lime content and the presence of toxic concentrations of chrominum, nickel and cobalt. The organs of the growth-stagnated trees assimilate large amounts of these elements (for example the ash of pine needles contained 0.6-0.75% Ni and 1.45-3.27% Co, the ash of the birch leaves: 2.2-2.3% Ni and 0.61-0.96% Co). Numerous data of the content of the soil profile and various organs of the coniferous and deciduous species can be taken from the original paper. Fertilization of hardwood plantations (alder, basswood, hazelnut) with ground limestone and diabase dust resulted in a considerable decrease of nickel and cobalt contents of the leaves. Diabase dust alone effected an increase in nickel uptake. The nickel and cobalt uptake depends on the soil reaction. When the soil acidity was decreased by liming, the nickel and cobalt content of the leaves was reduced. Liming increased the chromium and copper contents. Plant failure (common alder, basswood, hornbeam, poplar, hazelnut) was considerably reduced by fertilizing with lime and diabase dust. The favorable effect of these materials on growth became manifest not until the third year after application. At the present experiments are being made with gypsum and diabase dust on degraded serpentine soils, which show a better liming effect than quicklime or crushed limestone.

NĚMEC, A. 415

1955 a (The use of diabase dust and diabase-kapuzin mixture as fertilizers for the improvement of growth of nursery stock). Práce výzkum. Úst. lesn. CSR 9: 5-16. (Czech) A

Diabase dust, kapuzin (lignite) and a mixture of these two waste products(ratio 3:1) were used as fertilizers to ameliorate impoverished and extremely humus-deficient sandy soil of the forest

nursery at Žehrov in northeast Bohemia. The amounts of materials used per bed of 1 sq. m. were: 1 kg. kapuzin, 3kg. diabase dust, 6 kg. diabase dust, 4 kg. of diabase-Kapuzin mixture(ratio 3:1), and 8 kg. of diabase-kapuzin mixture. The fertilizers were applied to transplanted one-year-old seedlings of common alder, basswood, pedunculate and red oaks. The effect of the fertilizing became soon apparent in the leaf color and a general improvement of growth performance. The dark green coloring of the foliage of basswood and oak in particular was quite prominent, when treated with diabase or with a mixture of diabase and kapuzin. The diabase treatment caused a considerable growth increase, however, only when the larger amount of 8 kg. per sq. m. was applied. Kapuzin had no noticeable effect on the growth. In comparison to the two single treatments, the combination of diabase and kapuzin resulted in a noticeable growth increase. Judging from the analysis of foliage in the second growing season it is clear that the organic-mineral treatment, as compared to the single fertilizer applications, increases the potassium, phosphor and nitrogen contents of the foliage, the latter particularly in the basswood and oak foliage. The oak foliage also contained more carbohydrates and in general substances which take an active part in the synthesis of organic materials, in particular of proteins and of cellulose. The nitrogen and reducing carbohydrate content of the alder leaves was increased only by the application of kapuzin. An increased uptake of lime, magnesium, potassium and silicic acid by the alder foliage resulted from an application of diabase and, in particular, from an application of a diabase-kapuzin mixture. The phosphoric acid content, however, was decreased. The diabase and the diabase-kapuzin treatment also increased the molybdenum content of the alder leaves; the copper content was even doubled.

Foliage chlorophyl content of plants fertilized with the organic-mineral fertilizer was considerably higher than those unfertilized. The use of a diabase-kapuzin mixture can be recommended for improving the fertility of humus deficient and impoverished soils of forest nurseries, when not enough organic materials are available for the preparation of compost.

NĚMEC, A. 416

1955 b (The use of brushwood mulch and diabase dust for the amelioration of stagnating plantations on a degraded soil). Ann. Acad. tchécosl. Agric. 28: 825-840. (Czech) A

Mulching with heather and pine slash (in layers of 20 cm. deep) with an application of diabase dust (2 kg. per plant) was able to stimulate the growth of hardwoods (white alder, basswood, sycamore maple) in a growth-stagnated pine stand. The soil, a weathering product of gneiss, was degraded and impoverished as a result of litter removal. An application of diabase alone resulted in a considerable growth increase of the white alder (*Alnus incana*) because its requirement for nitrogen is covered by the assimilation of nitrogen from the air. The nitrogen and calcium uptake of the tree species was considerably increased by the combination of mulch and diabase treatments. The combined mulch and diabase application also stimulated the chlorophyl development in the leaves of sycamore maple (*Acer pseudoplatanus*) and basswood. The foliage of unfertilized and stunted alder contained the highest amounts of reducing sugar and invert sugar, whereas the lowest concentration was found in the foliage of alder, fertilized only with diabase dust. The soil under consideration was an azonal sandy loam, which was deficient in carbon, nitrogen, lime and to a lesser extent in magnesium and potassium. The deeper soil layers consisted of pure sand. Another fertilization experiment was carried out on an impoverished soil (gley-podzol with ortstein) supporting poor hardwood and softwood stands near Třeboň in South Bohemia. As a result of degradation and removal of the raw humus layer, this soil, a weathering product of tertiary sandstone, was extremely deficient in organic matter, lime, magnesium, potassium, and phosphor and was further strongly acid. In order to improve the growth of the stands, which had all but failed, it was necessary to fertilize with diabase dust in amounts of at least 3 kg., or preferably a mixture of quantity of diabase with an equal volume of raw humus per plant or seedbed. Open areas and open patches, created by group cutting had to be afforested with timber species such as common alder, basswood and oak. The application of diabase dust increased the germination capacity of the acorns in the seedbeds considerably as well as the number and growth of the oak seedlings.

The effect of the fertilizing was outstanding, the plant mortality had been strongly reduced. The nitrogen and phosphor assimilation in particular and the sugar synthesis (invert sugar content) of the alder foliage was stimulated by the fertilizing. An application of diabase dust in quantities of 3 kg. per planting hole or per oak seedbed made afforestation of the open patches with hardwoods quite successful, in spite of the fact that the dense, strongly acid raw

humus cover remained. Without this fertilizing the trees failed completely.

Němec, A. 417

1955 c (The reforestation of denuded areas in the forest district Křivoklát). Lesn. Práce 34: 269-274. (Czech) A

Extensive areas in the forest district Křivolát (spruce and pine) which were denuded 17 years ago as a result of snow and wind damage, and which are now covered with a dense growth of *Calamagrostis epigeois*, could until recently not be reforested by normal methods. The soil, derived from the Algonkian clay slates, is strongly acid and very deficient in soluble nitrogen and potassium as a result of long exposure. The trace elements are also seriously lacking. So far, most efforts to reforest the denuded areas failed after mechanical cultivation, removal of brushcover or after the application of biological measures. On the other hand, experiments with fertilizers led to remarkable results. Without tilling the soil or removing the Callagrostis cover, 2-year-old common alder, basswood and box elder (*Acer negundo L.*) were planted and treated with diabase dust and limestone. Three different methods of application were used: 1. surface application of 0.4 kg. limestone after planting, 2. adding 2 kg. of diabase dust to the plant holes and 3. treatment with both fertilizers in same quantities and by same methods as under 1 and 2. After three years all the basswood plants and ⅔ of the alder and box elder plants on the unfertilized area had died. The growth of the remaining trees was poor. The fertilizer treatments increased growth considerably and no plant losses were recorded. The combination of diabase and lime gave the best results.

Němec, A. 418

1956 a (The effect of the amelioration of degraded soils with basic rock dusts on the growth and nutrition of forest stands). Za sots. cel. Nauku 3: 301-304. (Russian) A

The Ao and A horizons of the different types of degraded soils (azonal soils, soils affected by ground water) are strongly acid and the leached horizons are highly deficient in mineral nutrients, nitrogen and trace elements. Some differences in the chemical properties of these soils are demonstrated. Excellent results were obtained by liming and fertilizing with basic rock dusts (basalt, diabase, amphibolite, alone or composted with raw humus) and

especially when these treatments were combined with the cultivation of perennial lupine and black alder. A brief discussion is devoted to the technique and the rate of application of rock dusts (quarry waste) and compost. Further some suggestions are made as to the use of basic rock dusts for the improvement of stunted plantations and stands on degraded and impoverished soils. Basic rock fertilizing reduces plant losses, improves the absorption of nitrogen, mineral nutrients and trace elements (Cu, Zn) and increases the chlorophyl content of the foliage of forest plants. The practical application of liming basic rock dust fertilizing permits the protection of degraded forest soils from total destruction, especially in pure stands.

NĚMEC, A. 419

1956 b (Improving the seed production of beech and basswood by fertilizing with basic rock dusts). Za sots. cel. Nauku 3: 305-308. (Russian) A

Poor seed production of beech and basswood occurs in particular on soils reduced in productivity as a result of degradation. Such soils are in general strongly acid and their A horizons are impoverished by the leaching of essential nutrients and trace elements. Successful fertilizing experiments were carried out with basalt or diabase rock dusts to stimulate seed production on degraded or impoverished sandy soils near Svijana in Žehrov (Bohemia) and on degraded gneiss soils near Vlašim in the forest districts Němčice. The foliage of seed bearing beech fertilized with basalt dust and that of seed bearing basswood fertilized with diabase dust contained considerably more essential nutrients and trace elements than the foliage of unfertilized non-seedbearing trees during the entire growing season. The Cu and Zn contents of the leaves, twigs and seed of the seed bearing trees appeared to be much higher than that of the leaves and twigs of the seedless trees. Moreover spectographical analysis of the leaves and twigs of the seed bearing trees indicated the presence of silver and lead. Increased seed production is possible by ameliorating the soil with an application of basic rock dusts which contain besides the essential nutrients important trace elements such as Cu, Zn, B and Ag.

NĚMEC, A. 420

1956 c (On the problem of reducing mortality after reforestation). Lesn. Práce 35: 243-246. (Czech) A

Considerable losses of plant stock occur after reforesting areas cleared off pine and spruce stands and old clear cut areas. In many cases these losses are quite excessive. It is emphasized that in most cases the losses are not caused by inferior quality of the plantstock or by poor planting but are the result of soil degradation with subsequent lowering of the fertility. The acid and nutrient deficient soils of the pure coniferous stands loose their ability to support the more demanding hardwood species. Less than three generations of pure coniferous stands will impoverish these soils to such an extent that even reforestation with spruce and pine will fail completely. In order to reduce plant mortality and to stimulate growth, the soil should be ameliorated by liming and by fertilizing with basic rock dusts. Treatment with compost or planting of perennial lupine and alder is recommended for soils deficient in humus and nitrogen. Losses of hardwood species amount to 50-100% on the ortstein podzols of the Quader sandstone areas in North and North-East Bohemia. Fertilizing with basic rock dusts can reduce these losses to a minimum. Considerable successes were obtained with the reforestation of old denuded areas, covered with Calamagrostis growth, when diabase dust (2-3 kg) was added to the planting holes.

NĚMEC, A. 421

1956 d (Amelioration of degraded forest soils). Lesnická knihovna (malá řada) 64: 295 pp. Státní Zemědělské nakladatelství, Praha. A

On the basis of his most recent experiments and research work the author discusses in detail the amelioration of degraded and impoverished forest soil with rock dusts. The introduction deals with the causes and the characteristics of soil degradation and the extent of impoverished soils in the republic of Czechoslovakia. Further the chief types of degraded forest soils are described, which were also discussed in a previously published book (The types of forest soils, 1943). Other chapters deal with amelioration treatments of degraded and impoverished soils in general, increase of soil humus content, biological amelioration and fertilizing with lime and basic rock dusts. One chapter is devoted to a discussion of the properties of basic rock dusts suitable for soil amelioration (basalt, diabase, gabbro, andesite, melaphyre, spilite, trachyte, felsofyrite, phonolite, gabbro-diotite, amphibolite, serpentine), with special consideration of their nutrient and trace element contents. Further the degree

of alkalinity and the choice of these materials is discussed. The second part of the book reports on the results of the amelioration of various soil types (degraded azonal soils, degraded rendzina soils, ortstein podzols and soils affected by ground water such as mottled soils, gley soils and gley podzols). In conclusion the results of the amelioration experiments are summarized and suggestions are listed for the amelioration of various degraded and impoverished soils with lime, basic rock dusts, brush and heather mulches, kapuzin (soft lignite) lupine cultivation and planting of broom (*Genista*), common alder, white alder, hazel and late blooming bird cherry (*Prunus padus*). Further suggestions are offered for the treatment of special soils (rendzina soils) with Thomas slag, organic-mineral fertilizers (humus-basalt and humus-diabase mixtures), compost, kapuzin-basalt and kapuzin-diabase. An extensive bibliography concerning the amelioration of forest soils is appended.

NĚMEC, A. AND S. BORISOV 422

1938 (Chemical properties of forest soil following alternate cropping in Slovakia). Ann. Acad. tchécosl. Agric. 13: 435-445. (Czech w/German and Russian summaries) Ba

Where logging slash was burned and the ashes scattered, the top 30 cm. of soil contained more P_2O_5 and K_2O than that on unburned areas, even after 7 years. Cultivation of oats, potatoes, and rye did not appreciably impoverish the soil. Spruce planted on unburned and uncropped control areas grew slowest; on areas cultivated without addition of ashes the growth was much less than where the ground was burned over prior to cultivation. On the heavy clay soil in question, cultivation of potatoes (but not oats and rye) had an unfavorable effect on spruce growth.

NĚMEC, A. AND S. BORISOV 423

1941 a (The effect of various potash fertilizer materials on the growth and nutrition of Norway spruce in forest tree nurseries). Ann. Acad. tchécosl. Agric. 16: 238-248. (Czech) A

Reports on experiments involving fertilization of 2-year-old spruce transplants with various potash fertilizer materials on a potassium- and phosphoric acid-deficient sandy nursery soil, with sufficient lime. The purpose of the investigation was to the effect of chloride and sulphate containing fertilizers on the growth and nutrient uptake of the needles and stems of the spruce plants. The

treatments, consisting of 40% potassium salt, Kalimag, potassium sulphate and Patentkali, were applied in combination with di-calcium phosphate. The size of applications was based on the results of a soil analysis and was to bring the concentration of phosphoric acid up to 190 mg. and of potassium up to 100 mg. soluble in 1% citric acid per kg. of soil. Spruce losses on the plots fertilized with 40% potassium salt were suddenly quite severe, after a dry period in June and July in the first year. Before plants died, the needles turned red in June. The spruce on the beds fertilized with sulphate and chloride free potassium salts showed on the other hand a deep green foliage and had a better height growth, were stronger developed and had a denser foliage than the unfertilized spruce. The fertilization with potassium effected a distinct increase of potassium uptake; the lime content of the spruce however had decreased. The magnesium content of the needles had considerably increased as a result of the potassium fertilization, in particular in the case of magnesium sulphate. Sulphate containing potassium fertilizers stimulated considerably the sulphate uptake of the spruce. Worth mentioning is the chloride uptake: needles of the spruce fertilized with 40% potassium salt contained over 3 times as much, the stems over twice as much chloride than the unfertilized plants or than the plants treated with sulphate containing potassium salts. The unfavorable effect of the 40% potassium salt was considered, under the given conditions, to be the result of the excessive uptake of chloride ions by the spruce; the harmful effect was augmented by the lack of moisture during the dry period. Chloride free potassium salts, containing potassium sulphate are therefore most suitable for the chloride sensitive spruce.

Němec, A. and S. Borisov 424

1941 b Über die Wirkung verschiedener Kalidüngemittel auf das Wachstum und auf die Ernährung der Fichte in der Waldbaumschule (The effect of various potash fertilizer materials on the growth and nutrition of Norway spruce in forest tree nurseries). Bodenk. u. PflErnähr. 25: 323-345. fa

The action of different potash carriers on the growth and absorption of nutrients by spruce in nurseries was investigated. Cl-free, sulphate bearing potash carriers, on soils rich in lime but poor in K and P, influenced the growth favorably. Fertilization with large applications of 40% potash fertilizer salts caused death or

growth reduction. Although fertilization with sulphate bearing potash salts on a soil with high exchange acidity gave no noticeable increase in the rate of height growth it resulted in denser needle formation and darker color of the needles. In this case also fertilization with large doses of 40% potash salt caused the trees to die. The unfavorable action of large doses of 40% potash salt was traced to the flooding of the needles and stems with Cl ions which was accentuated by moisture deficiency in the soil. Cl-free fertilizers containg K_2SO_4 were successfully used in large applications.

Němec, A. and S. Borisov 425

1947 (The nutrition and fertilization of elm). Ann. Acad. tchécosl. Agric. 18: 330-338. (Czech w/Russian and English summaries) A

Experiments were carried out in the forest nursery of Revnice near Prague with phosphorus and potash fertilizers applied to elm plants. The soil of the nursery is a sandy loam, poor in phosphoric acid and potash, rich in lime and magnesia, showing an almost neutral reaction. On the basis of a soil analysis the amounts of fertilizers were large enough to bring the content of phosphorus and potash in the surface layer of the soil up to optimum (250 mg. P_2O_5 and 160 mg. K_2O per 1 kg. of soil, soluble in 1% citric acid). The lime content of the nursery soil was adequate. The fertilizer treatment (853 g. calcium phosphate containing 28 p. 100 P_2O_5 and 198 g. potash containing 40 p. 100 K_2O, per 5 sq. m. of bed) caused an average of 15.9% height increase of the elm plants. The effect of the fertilizers on the nitrogen and mineral contents of the elm plants was considerable. The leaves of the fertilized plants showed a significant increase (27.5%) in phosphorus content, however not the stems or the roots. Potassium showed the largest increase, in all the parts of the elm plants (leaves 61.0%, stems 25.1% and roots 29.2%). The favorable effect of fertilizer treatment on the growth of the elm plants is due to an increase in the two nutrients in which the soil was deficient.

Němec, A. and K. Kvapil 426

1927 Über den Einfluss verschiedener Waldbestände auf den Gehalt und die Bildung von Nitraten in Waldböden (The influence of different forest stands on the content and formation of nitrates in forest soils). Z. Forst u. Jagdw. 59: 321-352, 385-412. Ba

Conifers prefer N in the form of ammonia, while hardwoods, especially beech, oak, and ash, derive their N chiefly from nitrates. Ammonia salts can be successfully used in pine and spruce nurseries to the extent of 28 g. per sq. m. Experiments by Weis have failed to establish a definite connection between local climatic conditions and nitrate content of soil. Presence of pitch and resin in soils under coniferous stands acts unfavorably upon nitrification bacteria and addition of 2% spruce gum reduces nitrification by 10%. Nitrate investigations of forest soils, methods of determination, and quantitative studies for soils of different forest regions in Czechoslovakia are discussed.

Němec, A. and B. Maran, 427

1939 (Results of experiments on the amelioration of impoverished forest soils in the Pilsen Basin). Lesn. Práce 18: 507-539. (Czech w/German and French summaries) A

Reports on amelioration experiments involving the fertilization of stagnated pine plantations on heath overgrown, strongly kaolinized gley-podzol formed from shale (Algonkium). The soil was strongly acid, was highly deficient in nutrients, and showed a high concentration of easily soluble aluminum compounds. The soil was for three consecutive years fertilized with Thomas slag or di-calcium phosphate, dolomitic limestone and calcium nitrate; altogether 15 kg. Thomas slag, 45 kg. limestone and 9 kg. calcium nitrate for 100 square meter. The soil was also partly seeded in with perennial lupine. The fertilization showed in the first years a considerable growth increase of the pine, as well as of the later planted species (white pine, hornbeam and alder). Quite conspicuous was the favorable effect of the lupine, preserved by a fertilization with Thomas slag or di-calcium phosphate and limestone (without calcium nitrate) and which had produced flowers and seed. On the other hand, the lupine on the unfertilized areas had perished. Also the plant losses on the fertilized area were considerably lower. The effect of the fertilization on the soil conditions was further studied; the lupine had a favorable effect on both the physical and chemical properties of the soil. The lime, magnesium, and potassium content of the needles had increased, and the aluminum and manganese content had decreased as a result of the fertilization. The fertilization and lupine cover had increased the nitrogen content by 100%.

1952 The use of organic fertilizers in *Cassia siamea* plantations. Rep. For. Dep. Nigeria 1950-1951: 32.

NIMMO, M. 429

1953 The 1945 broom and pine nursing experiments at Coldharbour, Wareham Forest, Dorset. Rep. For. Res., Lond. 1951-52: 31-33.

Experimental plantings of Sitka spruce, Norway spruce, Douglas fir and *Tsuga heterophylla* were made in 1945 on this difficult *Calluna* heathland. Five different treatments were given: (A) pure plots of the nursed species; (B) 2 row/2 row mixtures of the nursed species and Scots pine; (C) as (B) but with Corsican pine; (D) as (B) but with broom (*Cytisus scoparius*) sowings on prepared patches between both pine and nursed species; (E) nursed species intersown with broom patches. All the plants and the broom sowings each received an application of phosphate consisting of 2 oz. of bonemeal, with the exception of some control furrows along alternate edges of plots. Ground variation prevented proper statistical analysis of the experiments, but the differeneces between growth in the controls and in the phosphate and broom plots are such as to be beyond doubt. From the figures tabulated it is clear, that, given a successful broom crop, all the 4 species tried can be established by this method, whereas with phosphate alone the plants quickly go into check after the first 3 years. The mean height in inches at 7 years (6 for *Tsuga*) in plots with broom and phosphate (where broom is vigorous) is given below for the 4 nursed species (figures in parentheses are for controls): Sitka spruce 70.6 (19.7); Norway spruce 55.5 (12.3); *Tsuga* 53.0 (19.0); Douglas fir 96.7 (28.0).

Treatments (B) and (C) at present show poor results, but as the pine gains control of the surface vegetation, the nursed species are expected to pick up rapidly. Under treatment (D) the pines benefit from the broom at the expense of the nursed species except in the case of Sitka spruce. There are indications that the various species react differently when the variety of pine is changed from Scots to Corsican. The causes for failure of broom sowings in some sections are being investigated.

OBEL, R. 430

1954 Gödsling av skogsmark i Norge (Fertilization of forest areas in Norway). Växt-närings-Nytt 10: 58-59. (Swedish)

1950 (Some experiments on water culture of seedlings). J. Jap. For. Soc. 32: 305-310. (Japanese w/English summary) L

One year old seedlings of Sugi (*Cryptomeria japonica* D. Don) were grown in a complete nutrient solution including the following three different sources of N for 184 days, the solution being adjusted to pH 6.2 and pH 4.2, to observe the influence of NO_3-N and NH_4-N on the growth of seedlings: solution A: approximately equal portions of NO_3-N and NH_4-N as sources of N; solution B: only NO_3-N as source of N; and solution C: only NH_4-N as source of N. The following results were obtained: (1) the seedlings made better growth in solution A than B and C; (2) the seedlings made better growth at pH 4.2 than pH 6.2 in solution B, but in solution C the seedlings made better growth at pH 6.2 than at pH 4.2; (3) Knop's solution modified by the writers seems to be suitable for the culture of one year old Sugi seedlings.

One year old seedlings of Akamatsu (*Pinus densiflora* S. et Z.) were cultured in aerated and nonaerated nutrient solution for 194 days, each solution including two different sources of N (NO_3-N and NH_4-N), to observe the stimulating effect of artificial aeration of the culture solution on the growth of seedlings. The following results were obtained: (1) the seedlings made better growth in aerated than nonaerated solutions, (2) the effect of aeration in NH_4-N solution is more distinct than in NO_3-N solution.

OKSBJERG, E. 432

1954 a Et forsøg med vanding og gødskning af sandjord (An experiment with watering and fertilization of sand soils). Dansk. Skovforen. Tidsskr. 1954: 143-145. (Danish) AH

Heavy watering (corresponding to extra precipitation of 130 mm.) did not change growth in appearance of Norway spruce on sandy soils lacking in nutrients. This is especially noteworthy since precipitation is low in Denmark and almost every summer a water shortage occurs on most soils.

Heavy fertilization with nitrogen (supplemented by K and P) changed during a few weeks the color of spruce needles to dark green. Furthermore several xerophytic ground cover plants grew faster while *Hieracium pilosella*, that cannot respond in height growth, disappeared.

OKSBJERG, E. 433

1954 b Om udspringstid og skudstraekning i grankulturer (Time of flushing and growth of leader in young plantations of spruce). Hedeselsk. Tidsskr. 75: 49-59. (Danish w/ English summary) fa

The following results were obtained from 3 sets of measurements on 10- to 20-year-old early- and late-flushing spruce: (1) the date of flushing and the length of the growth period vary considerably in individuals, especially in cool springs, when the difference in flushing date may be as much as 3-4 weeks, as against 10-12 days in warm springs; (2) shoot growth of late-flushing spruce continues longer than that of early-flushing spruce, and the growth period is somewhat longer; (3) the growth period is shorter in a warm summer; (4) a long terminal shoot usually indicates a long growth period, but exceptionally a long top shoot may be produced in a short growth period. In plots treated with N both growth period and top shoots were longer than on control plots. In plots containing 500 plants each of early- and late-flushing spruce planted out in 1951 as 2-1 plants, 310 of the early-flushing spruce were seriously damaged and 165 of the late-flushing ones moderately damaged by frost in May, 1952.

OKSBJERG, E. 434

1954 c Redogörelse för några danska växtnärings-försök på Hedejord (Report of some Danish growth fertilization experiments on heath soils). Växt-närings-Nytt 10: 47-52. (Swedish) AH

An experiment established in 1952 on flat heath areas in Denmark was discussed. No reaction to P, K, and Mg., or the trace elements Cu, Zn, Mn, or B could be found. N gives a strong reaction first by changing the needle color and later, the year after application, by increasing the length of the topshoot. This experiment is also discussed under Oksbjerg, E., 1956 (Hedeselsk. Tidsskr. 77: 103-116).

OKSBJERG, E. 435

1956 a Om rødgranens naeringsoptagelse på fattig jord (About the uptake of nutrients of spruce on poor soils). Hedeselsk. Tidsskr. 77: 103-116. (Danish) AH

The results of three fertilization experiments, one minus experiment and two combination experiments, are discussed. The minus

experiment was designed by L. G. Romell according to the formula F-X, F being full fertilization (all elements) and X the element whose effect is to be determined. The stand was ten year old planted Norway spruce on poor sandy soils. The elements tested were N, P, and K together with microelements. Only N gave positive reaction. A linear correlation was found between the length of the topshoot and the N content of the needles above a certain value (0.80% of the dry matter of the needles). Likewise a linear correlation was found between the N content of the needles and the amount of N applied.

The combination experiments dealt with combination of N (three levels) and P + K (two levels) and the experiment mentioned previously (Oksbjerg, E., 1954. Växt-närings-Nytt 10: 47-52). The results were the same as in the minus experiments. Only N gave positive growth reactions. Within the investigated N-levels a direct linear correlation with wood production was found.

The remaining part of this article deals with discussion of results and results of other investigations.

Oksbjerg, O. and G. West-Nielsen 436

1953 Om rodfordaerverangreb. (Damage to spruce by *Fomes annosus*). Hedeselsk. Tidsskr. 74: 319-334. (Danish) fa

Replies to a questionnaire on the relationship between *F. annosus* attack and soil cultivation on reclaimed heathland show that attack is most severe on sites intensively cultivated. An investigation was made on a plantation established on heathland in 1874-77 and given various fertilizer treatments in 1921-22, to determine the relationship between attack and fertilizer treatment. The results indicate that attack is favored by fertilizer treatment and by removal of brushwood, and is least in the untreated belts between the treated plots where the brushwood from the plots was scattered. A study of the neighboring area treated with $CaCO_3$ with or without other fertilizer treatment shows that $CaCO_3$ favors *Fomes* attack, but that the relationship is not necessarily connected with the effect of the $CaCO_3$ on the pH of the soil. A possible explanation of the increased attack on plots that have been given heavy treatment with $CaCO_3$ or from which litter has been removed, is reduced water-holding capacity consequent on a reduction in the humus content of the soil. Results are tabulated. Further work on the effect of N fertilizers on *Fomes* attack is proposed.

Olson, R. V. 437

1944 The use of hydroponics in the practice of forestry. J. For. 42: 264-268. fa

Seedlings of both coniferous and deciduous species were grown from seed in nutrient solution in early spring and later transplanted to nursery beds for further development and hardening. Analysis of seedlings showed higher dry weights, a relatively high content of N, P, K, and a better balanced ratio of these elements than in seedlings raised in fertilized nursery soil. Growth and survival of transplants was satisfactory and it is suggested that the use of nutrient-solution technique will accelerate the production of mature planting stock and improve its quality. One of the important advantages of the method is the possibility of controlling closely the morphological development of seedlings through adjustment of the nutrient ratio.

Olson, R. V. and C. W. Carlson 438

1949 Iron chlorosis of sorghums and trees as related to extractable soil iron and manganese. Proc. Soil Sci. Soc. Amer. 14: 109-112. fa

A study was made of 3 groups of soils in Kansas: (1) samples from beneath chlorotic sorghum plants, (2) samples from round chlorotic *Quercus palustris*, spiraea and pine, and (3) samples from areas where no chlorosis was found. Analyses show that, while low extractable Fe contents, high Mn/Fe ratios, high pH values and the presence of free lime, appear to aggravate Fe chlorosis in plants, it seems that other, unknown, factors determine whether or not chlorosis actually develops.

Ono, M., N. Shibata, and H. Hoshino 439

1951 (Trials of fertilizers in the Suchi nursery. 1. Effects of nitrogen, phosphorus, potassium, and calcium on the growth of Sugi or Hinoki seedlings). Trans. Jap. For. Soc. 59: 85-88. (Japanese w/English summary) faA

Analysis of soils in the nursery showed deficiencies in available N, P, and K. The effects of additions of these minerals and also CaO on the growth of Sugi (*Cryptomeria japonica*) seedlings are tabulated and recommendations made on rates of application.

Ooyama, N. 440

1955 a (Studies on the substances inhibiting rooting of cuttings. 3. The method of treatment for getting the good rooting of the cuttings of "Ryowa sugi"). J. Jap. For. Soc. 37: 95-99. (Japanese w/English summary) Ba

To improve the rooting of cuttings of "Ryowa sugi", a so-called race of *Cryptomeria japonica*, the author tested various treatments. A 0.1-0.5% solution of $KMnO_4$ was effective in improving the rooting percent and amounts of roots regenerated. Hot water treatment increased the amount of roots regenerated but rooting percentage was not raised unless the cuttings were treated with a-naphthalene sodium acetate. Treatment with $AgNO_3$ solution showed negative effect unless hormone treatment was applied. The author believes that treatment with $KMnO_4$ is the most practical.

Ooyama, N. 441

1955 b (The effect of the leaf sprays of urea and folium on rooting of sugi (*Cryptomeria japonica*) cuttings). J. Jap. For. Soc. 37: 223-224. (Japanese w/English summary) Ba

Foliage spray of both urea and folium (a commercial preparation for foliage spray, containing 20% each of N, P_2O_5, K_2O) was effective in promoting the rooting of cuttings of 2 races of *Cr. japonica*. Urea was the more effective.

Oudin, A. 442

1939 Les amendements et engrais dans le reboisement (Fertilizers and measures for soil improvement in reforestation work). Rev. Eaux For. 77: 335-341. fa

The subject is discussed in relation to plantations with more or less degraded soils, brown forest soils, and endodynamo-morphic soils.

Parker, K. G., L. J. Tyler, D. S. Welch, and S. Pope 443

1947 Nutrition of the trees and development of Dutch elm disease. Phytopathology. 37: 215-224. Ba

Small budded trees, or trees grown from rooted cuttings, of *Ulmus americana* were potted in soil under different fertilizer treatments and inoculated with *Ceratostomella ulmi*. In the poor soil used, a complete fertilizer treatment (NPK) supported a better

growth than did any treatment lacking one or more of these elements. Likewise, disease development was less in trees receiving the complete fertilizer. Excessive amounts of the same mixture resulted in more severe disease than did moderate amounts. The severity of disease varied among trees receiving complete fertilizers with different formulae. Differences in hydrogen -ion concentration, brought about by addition of ground limestone, appeared to influence disease development. In general, trees making good growth were less severely affected by the disease than were poorly growing ones, but treatments favoring the production of a succulent type of tissue resulted in more severe disease.

PARMENTIER, S. W. 444

1951 Liquid feeding of trees by the jet method. Arborist's News 16: 65.

PEIN, F. 445

1953 Forstsamengewinnung und Forstpflanzenanzucht in den U.S.A. und in Deutschland (The production of forest seed and planting stock in the U.S.A. and in Germany). pp. 74-87. M. and H. Schaper, Hannover.

PERNET, R. 446

1953 L'effets du labour et de la fumure dans la reforestation d'un sol latéritique (The effects of plowing and fertilizing on reforestation of a lateritic soil). Mem. Inst. sci. Madagascar Ser. D 5: 229-250. A

The upper horizons of the soil differed considerably according to the type of vegetation. Chemical and mechanical analysis data are presented for a number of profiles to compare the effects of plowing and hole planting, each with and without fertilizing, on soil condition and composition on reforested slopes of annual burnt grassland, *Eucalyptus robusta* and *Pinus khasya*. Plowing and fertilizing both acted beneficially on soil regeneration and plant growth. Plowing increased soil depth, but tended to increase leaching. Hoe planting and subsoiling were preferable in being simpler to carry out, in limiting leaching, and where fertilizing was practiced, provided equally favourable conditions for growth. The effect of mineral fertilizing was markedly enhanced by addition of organic manures. Organo-mineral fertilizers based on the needs of the

species and soil can be applied either to the potted seedlings or to the plantation soil during subsoiling prior to planting.

PERRY, D. H. 447

1939 The effect of superphosphate on *Pinus pinaster*. Aust. For. 4: 12-14. aA

The impressive growth responses made by *Pinus pinaster* to application of phosphate on the soils mentioned, is described. This response is clearly illustrated by the growth rings and photographs are included to demonstrate this.

PESSIN, L. J. 448

1937 The effect of nutrient deficiency on the growth of longleaf pine seedlings. Occ. Pap. Sth. For. Exp. Sta. 65. 7 pp. L

A preliminary study was made of the effects of the deficiency of seven essential mineral nutrients on the growth and development of longleaf pine seedlings. Knowledge of such effects is especially useful in a nursery, since correct diagnosis of soil nutrient deficiencies must be made before the necessary remedial treatments can be applied.

PESSIN, L. J. 449

1944 Stimulating the early height growth of longleaf pine seedlings. J. For. 42: 95-98. fa

A progress report is given of an experiment begun in 1939 to determine (1) the conditions of ground cover most conducive to the growth of longleaf pine (*Pinus palustris*) seedlings and (2) the effect of watering, fertilizing and mulching on seedling development. After four growing seasons the outstanding result of the study is that the height growth of seedlings on plots that were denuded of ground cover has been significantly greater than those that were spaded, burned, or untreated except for the removal of woody plants—the height growth being 26.30, 5.68, 3.28, and 5.57 in. respectively. Supplementary treatment comprising watering, fertilizing, and mulching, either singly or in combination, appears to have had little or no effect. This study indicates the desireability of developing practical ways of removing competing vegetation from around longleaf pine seedlings in order to shorten or avoid the period of extremely slow early growth that is characteristic of the species under usual field conditions.

PIRONE, P. P. 450

1940 Chlorosis of pin oaks and its control. Shade Tree 13: 6. fa

In chlorotic pin oaks (*Quercus palustris*) normal green foliage was restored and twig growth increased within a few months following the insertion of collodion capsules of ferris phosphate into holes bored in the trunks. The chemical was used at a rate of 5 g. per inch of trunk diameter, and the holes (½ inch diameter) varied from 1-4 according to the diameter of the tree. The capsules were inserted in April, when the trees were still dormant, and the holes plugged with grafting wax. Trees thus treated had mostly recovered after 3 months, whereas controls were still chlorotic. Soil treatments with a mixture of powdered sulphur, aluminum sulphate and ferrous sulphate effected some improvement, but less than that obtained from trunk injection.

PIRONE, P. P. 451

1951 Foliage application of nutrients. Proc. nat. Shade Tree Conf. 1951: 23-25. fa

As a result of experiments over 3 years it is concluded that both N and P can be absorbed directly by leaves when applied in a complete-nutrient spray in sufficient concentration. The resulting increase in growth in treated plants was healthy and balanced, with no indication of unbalanced or over-succulent growth, which would occur if only one major nutrient, such as N, was entering. Among species treated were European limes, London plane, pin oak, Norway maple, American elm, box and holly. The sprays used were solutions of one or other of two complete commercial fertilizers, Rapidgro and Nutreen.

PISKAREV, A. N. 452

1951 (Questions of the fertilizing of the oak in nest sowings of tree belts). Soviet Agron. Moscow 5: 24-32. (Russian)

PLICE, M. J. 453

1944 Uptake of minerals by trees in successive years. Proc. Okla. Acad. Sci. 24: 60-73. a

Composite leaf samples of twenty tree species were analyzed for ten components in five successive years. The land area involved was less than one quarter section and represented only one soil

type. There was a direct correlation between amount of mineral uptake and seasonal wood increment. There was little correlation between mineral uptake and precipitation, as such, but mineral uptake was correlated with ground water table levels.

POACH, W. A. 454

1949 Plant injection methods. Sci. Hort. 9: 55-61.

POSEY, H. G. AND J. T. MAY 455

1954 Some effects of sawdust mulching of pine seedlings. Leafl. Ala. agric. Exp. Sta. 42: 4 pp.

PRIDHAM, A. M. S. 456

1938 Growth of pin oak (*Quercus palustris*) Proc. Amer. Soc. hort. Sci. 35: 739-741. BaA

Trees selected for uniformity were planted in the fall of 1930 and the spring of 1931 in two soil types. Planting was done in 3 ways—normal, soil left loose about roots, soil packed tightly about roots. Pruning was also done in 3 ways—normal, branches pruned to top of tree, branches cut back along trunk. Trees were fertilized with ammophos. Observations were made on twig elongation and on trunk diam. In 7 years' growth, the influence of the individual season was the most important factor. This was followed in order of magnitude by the influence of soil type and by date of planting. Variance due to the other treatments was low and generally less than that due to interaction with season, location and date of planting.

PRIDHAM, A. M. S. 457

1940 Response of mature American elm to ammonium sulfate as a fertilizer. Proc. Amer. Soc. hort. Sci. 37: 1075-1076. faA

Sulphate of ammonia (16% NO_3) used as a fertilizer for mature American Elm did not produce any marked stimulation in the growth of the trees when applied in the spring of the year and at a rate of one pound of fertilizer for each inch of trunk diameter.

PRIDHAM, A. M. S. 458

1941 Response of red oak to fertilization with ammonium sulfate. Proc. Amer. Soc. hort. Sci. 39: 439. fa

Application of ammonium sulphate or 6-8-4 complete fertilizer improved foliage color and delayed autumn coloration but failed to produce any marked increase in diameter increment.

PRONCHENKO, V. F. 459

1942 (Results of ten-year liming experiments in a pine plantation). Pedology, Leningr. 1942: 42-53. (Russian w/English summary) fa

The experiment described was conducted in the Moscow region during 1930-39 in a first-quality *Piceetum oxalidosum* stand planted in 1870-71. Liming resulted in a reduction in the acidity of the soil which had previously been very high; in an increase in mobile Ca, P_2O_5, and N; in the appearance of a thick undergrowth of red alder, and of vegetation indicative of a rich soil; and in improved diameter growth in the spruce stand.

QUAIRIERI, C. J. 460

1926 Les expériences de Caulille (Suite et fin) (The experiments at Caulille (results and conclusions)). Bull. cent. For. Belg. Soc. 33: 110-120, 183-190. Ba

In mixed plantations established in 1902, 1904, and 1908 in the communal forest at Caulille, indications are that *Pinus banksiana* is dominating *P. silvestris* and suppressing *P. maritima* in the smaller groups. It is believed that in plantations, mixtures should be of clumps of at least 10 × 10 m. to a single species. Plots of *P. silvestris* were given various applications of phosphate, 2 untreated plots serving as a check. After 15 years the check plots surpassed the treated, those receiving the smallest amount of fertilizer being better than those with heavier applications. In a test of comparative value of species, *P. laricio* from Corsica produced better trees than *P. silvestris* and *P. strobus*. Although the plantations of *P. silvestris* are too young for definite conclusions, the trees from the Campine were superior to those from Sweden and the vicinity of The Hague. Other tests also indicated that local seed was superior to that collected at considerable distances. In another series of fertilizer tests, on very poor, dry, and sandy soil, plots treated with phosphate did better than those treated with potassium, phosphoric acid, Kainite, lime, or complete fertilizer. Cultivation and fertilizing at the time of planting was more effective than cultivation alone, or fertilizing alone, or fertilizing and cultivation several years after planting.

Queensland Department of Agriculture 461

1947 Nutrient requirements of *Pinus caribaea* and *Pinus taeda*. Rep. Dep. Agric. Qd. 41

Queensland Department of Agriculture 462

1951 a Treatment of nursery beds. Rep. Dir. For. Qd. 1950-51: 6. fa

Results of initial experiments in the use of filter press to maintain fertility in exotic nursery beds at Tuan Creek, Queensland, are most promising. Results to date show that equivalent applications of filter press and farmyard manure have given similar reponses. The filter press has the additional advantage of not introducing weeds to the nursery. Fears that its continued application might cause a pH unsuitable to mycorrhizae have been allayed by the fact that a number of mills produce a filter press having an acid reaction.

Queensland Department of Agriculture 463

1951 b Forest nursery experiments: fertilizer trials. Rep. Dep. Agric. Qd. 1950/51: 50. fa

In two fertilizer trials on the effect of N, H_3PO_4, and potash on *Pinus caribaea* seedlings, marked increase in growth was obtained only from phosphate. N depressed growth. Cu, Zn, B, and Mo applied to the soil had no effect on the growth rate of exotic seedlings. In fertilizer trials on *Araucaria cunninghamii* using N, H_3PO_4 and potash with and without added animal manure, positive responses to H_3PO_4 were obtained; manure-treated blocks were superior to controls. This superiority is thought to be associated either with an increase in moisture-holding properties of the soil or with an induced and more favorable microflora, as ample nutrients were supplied to the controls. In experiments using molasses and formalin as pre-planting treatments on beds that for many years had had heavy applications of sawdust, increased growth was obtained from both treatments, especially from that with molasses. The molasses treatment improved the soil structure by giving increases of 21 to 25 in the percent aggregation.

Queensland Forestry Commission 464

1952 Phosphate application to *Pinus taeda*. Rep. Dir. For. Qd. 1951-52: 7-8. fa

Measurements of merchantable volume to 3 in. diam. u.b. in 1951 on *P. taeda* planted in 1931 in soil with total P_2O_5 in the surface 4 in. of 55 ppm., and given application of superphosphate in 1939, were as follows: no addition (total P_2O_5 55 ppm.) 1229 cu. ft.; 190 lbs. superphosphate/acre (total P_2O_5 90 ppm.) 1923 cu. ft.; 383 lbs./acre (125 ppm.) 2404 cu. ft.; 818 lbs./acre (205 ppm.) 3398 cu. ft.; and 1580 lbs./acre (345 ppm.) 3425 cu. ft.

RAMANN, E. 465

1911 Die zeitlich verschiedene Nährstoffaufnahme der Waldbäume und ihre praktische Bedeutung für Düngung und Waldbau (The periodic variation in the nutrient absorption by forest trees and its practical importance for fertilization and silviculture). Z. Forst u. Jagdw. 43: 747-753.

RAYNER, M. C. 466

1939 The mycorrhizal habit in relation to forestry: III. Organic composts and the growth of young trees. Forestry 13: 19-35. BaA

An account of experiments designed to test the conclusion that the stimulating effects on growth of seedling conifers observed to follow the application of organic composts "differs essentially from that of ordinary manures". Pot experiments were grown in series supplied respectively with composts and with the equivalent amounts of lime, available N, K_2O, and P_2O_5 contained in them, calculated from the results of Mitcherlich experiments with oats. Results are expressed in a table showing final dry weights, and by photographs of the experimental plants. They prove that increase in the supply of available nutrients plays an insignificant role in the maintenance of healthy and vigorous growth, confirm previous conclusions respecting the presence of actively deleterious substances in the experimental soil, and show that addition of composts puts an end to their production whereas that of equivalent inorganic salts is practically without effect. The bearing of these results on the hypothesis of compost action previously put forward is discussed.

RAYNER, M. C. 467

1945 Trees and composts. J. Minist. Agric. 51: 567-569. fa

Since 1933 the writer has been investigating the causes of poor tree growth on Wareham Heath (southern England) and elsewhere.

This article gives a brief account of the Wareham experiments and the successful use of compost treatments to re-establish soil fertility.

RAYNER, M. C. 468

1947 Behavior of Corsican pine stock following different nursery treatments (*Pinus nigra* var. *calabrica* Schneid.). Forestry 21: 204-216. FaA

Describes an experiment to compare the survival and growth of 2-year-old Corsican pine (*Pinus nigra* var. *Calabrica*) transplants of different nursery origin on poor heathland and in an exposed position. Plants of 3 different origins were used: (1) Raised in the same poor heath soil with addition of compost; lined out for 1 year in similar soil with addition of compost. (2) Raised by "standard nursery methods"; lined out for 1 year in the same nursery. (3) Raised as in (1); lined out for 1 year as in (2). The plantings were duplicated in each group, one series being supplied with phosphates (basic slag) at planting. All treatments were quadruplicated in randomized plots.

Plants of origin (1) were greatly superior to those of (2). The death rate of the latter was very heavy, and was increased by a supply of phosphate at planting. Those of (3) occupied a medium position. Phosphate at planting helped growth in all series. The root systems of plants raised in heath soil with compost were well supplied with short roots and mycorrhiza at planting and throughout growth. Those of the nursery transplants were very deficient in short roots and devoid of mycorrhiza.

The experiment illustrates the fact that seedlings of Corsican pine, raised in soil conditions ensuring possession of a normal root system with adequate mycorrhizal equipment, carry their constitutional vigor into the forest and even to poor soils on non-forest type. The significance of this for treating soils in tree nurseries generally, is discussed.

REIHLING, K. 469

1940 Ein Versuch mit Besenginster (*Sarothamnus scoparius*) auf degradiertem mittlerem Hauptbuntsandsteinboden (An experiment with broom (*Sarothamnus scoparius*) on a degraded middle Hauptbundsandstein soil. Allg. Forst u. Jagdztg. 116: 197-228. fa

The soil of the plots studied is naturally acid and tends to form raw humus. Available bases and P and N compounds tend to fall

below the limit essential for good tree growth. Broom and lupine improve the soil but need even more available nutrients than the trees. Where the C/N ratio in the organic material is higher than 20:1, Ca is required (as $CaCO_3$ or CaO) in addition to N (as $Ca(NO_3)_2$). The fertilizer is best applied by scattering it on the surface before the leaves fall, without cultivation. Broom seed should be inoculated before sowing.

REINHOLD, F. 470

1952 Basaltmehl als forstliches Düngemittel (Basalt dust as a forest fertilizer). 46 pp. Süddeutsche Basaltwerke, Immendingen, Baden. fa

Reviews literature on trials to date, with discussion of reasons for the beneficial effects of basalt dust on e.g. poor diluvial sands and soils derived from bunter sandstone, the composition of basalt and basalt tuff from Immendingen, and comparison of costs with those of other fertilizers.

REMEZOV, N. P. 471

1938 (Nitrogen fertilizing in pine forests). Soviestsk. Bot. 6: 34-51. (Russian) fa

From investigations near Bryansk it appears that in stands with a ground vegetation of mosses and bilberry, N-nutrition consists almost exclusively of ammonium salts, while in those with an undergrowth of shrubs, and wood sorrel, nitrate salts are also absorbed to some extent. Ammonification, and especially nitrification, are intensified by clear-cutting.

RENNIE, P. J. 472

1953 Research into the physical and chemical properties of forest soils: rooting investigations. Rep. For. Res., Lond. 1951-52: 109-115. L

One portion of the investigation indicates that basic slag applied to Sitka spruce appeared to increase "root density" twofold in the 0-30 cm. zone, and fivefold in the 40-50 cm. zone on a very stony subsoil.

RENNIE, P. J. 473

1955 Uptake of nutrients by mature forest trees. Plant and soil 7: 49-95.

RETAN, G. A. 474

1914 Effective fertilizers in nurseries. For. Quart. 12: 34-36.

RHEINWALD, H. 475

1933 Bodenuntersuchungen auf dem Owinger Forstdüngungsversuche (Soil investigations at the Owinger forest fertilization experiments). Forstwiss. Zbl. 55: 221-231. Ba

Investigation in 1929 of the bacterial and plant nutrient contents of spruce plots fertilized in various ways in 1906 indicated that although the stimulation of height growth on fertilized plots ceased after about 10-12 years, the favorable effect on the composition of the soil lasts much longer. Probably the increased amount of P_2O_5 and K in the upper soil layers will favor natural reproduction when the present stand is cut.

RICHARDS, B. N. 476

1956 The effect of phosphate on slash and loblolly pines in Queensland. Res. Notes For. Serv. Qd. 5: 1-11. GKV

The disease known as fused needle which occurs in plantations of *P. taeda* and *P. elliottii* in Queensland can be corrected by the application of phosphatic fertilizers.

A minimum total P_2O_5 content of 135 ppm. in the surface soil is required for healthy growth of *P. taeda* and about 110 ppm. for *P. elliottii*. Where phosphorus is deficient, growth of plantations is slow, and financial yields are much delayed, or in extreme cases, practically non-existent.

The optimum phosphate content of the surface soil appears to be about 210 ppm. for *P. traeda*, and perhaps 150 ppm. for *P. elliottii*.

Finely ground rock phosphate is just as efficient as superphosphate in reducing the incidence of fused needle and stimulating the growth of pines. Initial response to rock phosphate and to superphosphate occurs in the same year, but is not as great with rock phosphate as with superphosphate. Rock phosphate has the advantage of possessing approximately double the P_2O_5 content of equal quantities of superphosphate.

Broadcast applications are preferable in older plantations, but when treatment is applied at planting, application to the individual stems appears to be satisfactory.

It is estimated that the future annual requirements of Queensland Forestry for rock phosphate is of the order for 225 tons.

RICHARDSON, S. D. 477

1953 Root growth of *Acer pseudoplatanus* L. in relation to grass cover and nitrogen deficiency. Meded. LandbHoogesch., Wageningen 53: 75-97. BaA

The observations were made in a root observation chamber. The presence of grass (*Lolium perenne*) depressed root growth rate, shortened the period of active growth, reduced the density of root hairs and restricted both rooting depth and lateral spread of sycamore roots. Shoot growth and leaf development and lammas shoot formation were inhibited. A deficiency of N reduced the size and growth of sycamore roots, but increased the elongation of grass roots. Shoot growth and leaf development of both sycamore and grass were inhibited. Active growth of grass roots started some three weeks earlier in the spring than that of sycamore roots, and was considerably more rapid. The absorbing surface of grass roots were greater than that of sycamore roots in the same volume of soil. The absorbing life of grass root hairs is longer. Both N deficiency and grass increased the ratio root/shoot dry weight in sycamore transplants. Height increment was not a sensitive index of dry matter production in sycamore transplants. Under the conditions of this experiment the effects of grass were more marked than those of N deficiency.

RIKER, A. J. ET AL. 478

1947 Some chemical treatments and their influence on damping-off, weed control and winter injury of red pine seedlings. J. agric. Res. 74: 87-95. fa

A seed treatment with mercuric phenyl cyanamide and cadmium oxide, supplemented by a soil treatment with calomel, was relatively effective against damping-off from *Pythium* and *Rhizoctonia* in Wisconsin's sandy soil. A soil treatment with tetramethyl thiuramdisulphide was relatively effective not only against this damping-off but also against many weed seeds and winter injury.

ROBAK, H. 479

1950 Growth check in young spruce on heath in western Norway. Abstr. Int. bot. Congr. 7th, Stockh. X: 1. fa

Considerable variations in soil quality are found on the west Norwegian heaths, where the vegetation is dominated by *Calluna*, other ericaceous spp. and *Empetrum*. Although of podzolic nature

the soil is seldom typically podzolized. The humus layer is usually fairly rich in mineral substances and has a high water content for most of the year. On *Calluna*- dominated heaths young spruce suffer a growth check lasting for some 10-30 years, according to the variations in humus quality. They usually recover, however, and make good growth, having developed a widespread root system. When grown under *Pinus sylvestris* or *P. mugo*, spruce escapes "check" if the shelter is removed gradually, leaving no openings for reinvasion by *Calluna*. Some growth response has been obtained with spruce on "check soil" by heavy liming and working of the soil in large plant holes during the autumn before planting. A direct addition of about 5 g. of limestone meal to each plant, combined with the so-called "flatroot" planting, has successfully eliminated "check" for 4-5 years, i.e., brought the spruce beyond the "check" period, on the mildest type of *Calluna* humus. Superphosphate has also given a distinct response. Considerable growth promotion is still shown where, in 1931, $CaCN_2$ was added in quantities sufficient to kill the *Calluna*.

Robinson, W. O. and G. Edington 480

1945 Minor elements in plants and some accumulator plants. Soil Sci. 60: 15-28. fa

Includes tables showing the partial inorganic composition (dry weight basis) of the leaves of *Symplocos tinctoria* and *Lycopodium flabelliforme* (both rich in aluminum); the inorganic composition of mature hickory and pecan leaves; and the rare earth content of hickory leaves. Notes are given on the occurrence of aluminum, arsenic, barium, boron, cobalt, copper, fluorine, iodine, manganese, molybdenum, rare earths, selenium, silicon, vanadium, and zinc in plants generally.

Robinson, W. O. and G. Edington 481

1954 Availability of soil molybdenum as shown by the molybdenum content of many different plants. Soil Sci. 77: 237-251.

Rognerud, T. 482

1954 Salpetergödsling av skog på mager sandjord (Nitrate fertilization of forest on poor sandy soil). Växt-närings-Nytt 10: 67-69. (Swedish)

1951 Aufforstungs- und Meliorationsprobleme auf armen Waldböden (Reforestation and amelioration problems on poor forest soils). Mitt. StForstverw. Bayern. 26: 179-194. Van

Discusses theoretical and practical basis for the restoration and the maintenance in productivity of the impoverished pine soils. Practically all pure pine stands and many Norway spruce stands in Germany show stagnated growth as a result of soil degradation. The key to lasting soil improvement is to convert raw humus into mild or, where the former is not available, to provide the latter from other sources. The soils concerned here are derived from Keuper, diluvial, Cretaceous and iron stone sands, and phyllite, mica-schists and Jurassic materials. By breaking up the raw humus and mixing it with the mineral soil valuable mild humus will be formed providing that in addition lime and nitrogen are applied, the latter in the form of artificial fertilizers or by cultivating lupine. The nitrogen is indispensible as liming causes autoxydation whereby the lignin fraction adsorbs the raw humus nitrogen in ammonia or amino forms, which therefore does not become available to the plants. The importance of soil tillage increases with soil degradation. The most effective way of tilling the soil under poor pine stands is full plowing whereby the soil slices are completely turned over, broken up and mixed with raw humus and lime. On soils treated in this way, a wider choice of species is possible, moisture conditions are improved and seeding and planting cost is reduced. The use of the "Bifang" (high-ridge) plow is necessary where the heather cover or hardpan are less manageable. For the reduction of heavy heather growth, herbicides are under trial. This soil treatment should be undertaken in the summer or fall preceding spring planting. Liming is of prime importance for the nutrition of plants, and above all for the formation of mull humus. The amounts of lime to be used varies with the acidity of the soil and the stability of the raw humus layer. Normal applications are 4000-10,000 kg. per ha., ⅓ to ½ of this before and the remainder after plowing. Increased lime contents of the surface soil is of particular importance for the successful growth of lupines. Makes of lime spreaders for use in forestry are quoted. In addition to soil cultivation and liming soil improving vegetation should be introduced. Lupine (5-7 kg. of seed per ha) is often assisted by an application of Thomas slag. Broom is best for iron sandstone soils, it is, however,

sensitive to lime and needs adequate potassium. The effect of the leguminous plants is increased by planting soil-improving shrubs and trees, which will also improve the microclimate in open areas. *Alnus incana* is planted 2 × 2 m. Birch is sown directly in the fall or winter (5-7 kg. seed per ha). Aspen and willow seed in naturally from nearby stands. Other species used for site improvement are *Alnus glutinosa*, *Rhamnus frangula*, *Prunus padus*, *Robinia pseudoacacia* and many others. In order to maintain proper humus conditions, pure pine stands should be avoided. Penduculate, sessile and red oaks, alder hornbean, *Robinia*, poplar, birch and aspen are suitable for auxiliary species, the proportion of which, Schödel recommends, should rise to ⅔ of the population on the worst soils. The most valuable conifers for reforestation are *Pinus sylvestris*, *P. strobus*, European and Japanese larch, Douglas fir and spruce. Value is placed on initial high density. Pine and larch are planted as 1-year seedlings, most hardwood species as well-developed 1-to 2-year-old seedlings. Continued research is still needed, although improved growth of the plantations has already been shown.

ROSENDAHL, R. O. 484

1939 The effect of varied fertilizer treatment on loblolly pine seedlings in Chapel Hill Nursery. M. F. Thesis, Duke Univ., Durham, N.C.

ROSENDAHL, R. O. 485

1943 The effect of mycorrhizal and nonmycorrhizal fungi in the availability of difficultly soluble potassium and phosphorous. Proc. Soil Sci. Soc. Amer. 7: 477-479. L

Red pine (*Pinus resinosa*) and American elm (*Ulmus americana*) were grown in sand cultures in which 40- to 60-mesh orthoclase and apatite were, respectively, the only potassium and phosphorus sources.

Pine seedlings grown in sand-orthoclase media inoculated with *Boletus fellus* showed much greater growth and potassium absorption than control seedlings or those inoculated with *B. granulatus* or *Amanita muscaria*. Seedlings inoculated with *B. fellus* and transplanted to a mycorrhiza-free prairie soil developed mycorrhizae and showed greater growth and survival than other seedlings. Inoculation failed to stimulate the growth of pine seedlings in sand-apatite cultures.

Elm seedlings in sand-orthoclase media were not stimulated by any fungi, while the growth of elm in sand-apatite media was increased by the presence of mycorrhizal and nonmycorrhizal fungi alike. Chemical analyses indicated that both types of fungi increased the solubility of the phosphorus of apatite, though no increase in the solubility of the potassium of the orthoclase was detected.

ROSENDAHL, R. O. AND C. F. KORSTIAN 486

1945 Effect of fertilizers on loblolly pine in a North Carolina nursery. Plant Physiol. 20: 19-23. fa

The data given in this paper were obtained from field tests with three commercial fertilizers (ammonium sulphate, superphosphate, and potassium chloride) applied singly and in all possible combinations to plots of loblolly pine in the nursery of the United States Conservation Service near Chapel Hill, North Carolina. Of the seven single and combination treatments used, ammonium sulphate alone was shown to be effective and financially justified in the amount applied (550 lbs. per acre).

ROTH, E. R., E. R. TOOLE, AND H. HEPTING 487

1948 Nutritional aspects of the littleleaf disease of pine. J. For. 46: 578-587. faA

Shortleaf pines (*Pinus echinata*) with littleleaf disease show a marked deficiency of N and Ca in the foliage and a somewhat lower Mn, Al and Cu content than healthy trees. In extensive fertilizer experiments, only soil amendments with large amounts of inorganic N were effective against the disease. Nitrate or ammoniacal N, at rates exceeding 200 lbs. of available N per acre, prevented the onset of littleleaf to a notable degree, and either checked the disease or induced noticeable improvement in diseased trees, but salts or combinations of salts of the following elements (applied to the soil, or as foliage sprays, or both) had no beneficial effect: Na, P, K, S, Ca, Zn, Mg, Mn, Cu, Mo, Co, Ni, B and Fe. The rate at which trees became affected and their subsequent decline were hastened for the first few years by the addition of large quantities of hardwood or mixed pine-and-hardwood leaf mold. Applications of salts of P, P + K, B, and dolomite, appeared to accelerate the decline; horse manure and compost had little effect over a 3-year period. Working of fertilizers into the soil was not helpful, and, when done with a mattock, proved definitely harmful. The disease seems

to be associated with a failure to assimilate an adequate amount of N from the soil, for there was no N deficiency in many of the soils involved. The harmful effects of hardwood leaf litter and mold support this theory, since large applications of raw organic matter are known to induce temporary N starvation. It is highly probable that the failure to absorb enough N is due to faulty mycorrhizae and the killing of fine roots by soil fungi. The accelerated decline in soil cultivated with a mattock is of interest in this connection, since root injury was unavoidable during this process.

ROTHAMSTED EXPERIMENTAL STATION 488

1951 Nutrition problems in forest nurseries. Rep. Rothamst. exp. Sta. 1950: 40-41. fa

Sitka spruce seedlings showed large response to each of the major nutrients in experiments on very acid soils, but in some of these experiments composts well supplied with N, P, and K gave better results than inorganic fertilizers. It appeared that fertilizer N applied in the seed beds in the spring and in an early summer top-dressing had been leached out of the surface soil during the very wet summer and autumn before the period of most active growth.

In the neutral or slightly acid soils of old nurseries, Sitka spruce seedlings generally make very poor growth, even when well manured with fertilizers or compost. In 1950 at several nurseries there were striking responses on such soils to acidification in previous years by $(NH_4)_2SO_4$ or S. Repeated dressings with $(NH_4)_2SO_4$ appear to provide a safe method of supplying available N and at the same time acidifying the soil. If this kind of result can be repeated under other conditions, it may offer a simple, practical remedy for an acute example of "soil sickness".

The hypothesis that the beneficial effects of soil sterilization are due to the elimination of soil fungi harmful to or competing with the roots of conifer seedlings, was tested in several nurseries and in a series of pot experiments. Many fungicides and two antibiotics were added to the soil or applied as seed dressings. Several of these materials reduced early deaths by damping off in the pot experiments, and others damaged the seedlings. None of them, however, approached steam or formalin in their general effects on growth. These results indicate that the control of soil fungi may be a relatively unimportant factor in the effects of steam, formalin and acidification in improving to growth of Sitka spruce seedlings on "Sitka-sick" soils.

An indication of the complexity of formalin effects was given in two experiments on very acid nurseries, one on heathland and the other in a clearing in a conifer forest. On plots without formalin, inorganic fertilizers gave better plants than compost. Previous treatment with formalin greatly improved growth on the compost plots but had no effect on the fertilizer plots. The appearance of the plants suggested that those with formalin and compost received large quantities of available N late in the season. Presumably the formalin retarded the breakdown of proteins from the compost.

ROTHAMSTED EXPERIMENTAL STATION 489

1954 Nutrition problems in forest nurseries. Rep. Rothamst. exp. Sta. 1953: 46-50. fa

In past years some of the benefits from formalin treatment, especially in older nurseries and on neutral soils, have been ascribed in part to the inhibition of nitrification and consequent accumulation of NH_3. Additional evidence on this point was obtained in 1953 from experiments at 6 nurseries, testing 4 alternative forms of N fertilizer supplying 9 g. N/sq. yd.—(a) formalized casein applied a month before sowing; (b) $Ca(NO_3)_2$, (c) "Nitro-Chalk", and (d) $(NH_4)_2SO_4$ applied in two summer top dressings—(1) with and (2) without formalin treatment. In plots without formalin treatment, growth was poor throughout, particularly on (b) plots; the superiority of (d) over (b) was significant in 3 out of 4 experiments. (e) being intermediate. Formalin treatment greatly increased growth for all N treatments, and at the poor, established nurseries gave crops resembling those grown in very acid, newer nurseries; but in both cases (a) gave much superior results to (b), (c), or (d) possibly due to its supplying N in a wet season before the inorganic fertilizers were given as top dressings. The experiments strengthen the view that conifers profit from receiving their N as NH_4.

In several experiments chlorpicrin injected in January or February 1953 gave improvements similar to those from formalin, but time of application had no effect on chlorpicrin.

SALOMON, M. 490

1953 The accumulation of soil organic matter from woodchips. Proc. Soil Sci. Soc. Amer. 17: 114-118. faA

Pine (*Pinus strobus*) or Oak (*Quercus velutina*) chips were mixed with a sandy loam topsoil at a rate of 10 tons/acre and the

resulting level of NO_3-N and the soil reaction were observed. For the experiments, a series of galvanized iron cylinders 18 in. in diameter and 36 in. deep were sunk to ground level and filled with a silt loam subsoil and 6 in. of a Merrimac sandy loam, this topsoil being mixed with the chips. Oak chips decomposed more rapidly than pine. Although 55 to 85 % of the wood chips decomposed, organic matter accumulation proved to be small; there was some indication of its being greater in soils at pH 5.0-5.5 than in those at pH 6.0-6.5. The relationship between C as determined by the H_2CrO_4 titration method, and total C, did not change appreciably after two years of chip decomposition. Chip treatment caused no significant difference in the amount of H_2CrO_4 oxidizable C and the effect on total soil N and soil reaction was small. Accumulations of NH_3 were negligible. After 2 years of decomposition the addition of the equivalent of 150 lbs./acre NO_3-N gave highly significant increases in the yields of beet and spinach. Wood chip residues did not depress plant growth. Small chips gave higher yields than large chips. The addition of 100 and 150 lbs./acre NO_3-N to beet and spinach respectively, overcame any depressing effects of additions of 10 tons of small pine chips. With low available N, wood chips depressed the growth of beet and spinach, though, this depressing effect ceased after 12 months' decomposition.

Sato, Y. 491

1954 (Research on methods of treatment to increase the increment of wood-fibre plants, i.e. those suitable as raw material for pulp, and to increase their wood-fibre content 1) *Betula maximowicziana*). Res. Bull. exp. For Hokkaido 17: 23-30. (Japanese w/German summary)

Sato, Y. and K. Muto 492

1951 (Fundamental studies on the nutritional physiology of *Larix kaempferi* and *Thujopsis dolabrata*). Res. Bull. exp. For. Hokkaido 15: 1-62. (Japanese w/English summary) fa

Seedlings of *L. leptolepis* and *T. dolabrata* were transplanted from the seedbed at respectively 25 and 20 days old, to nutrient solutions, renewed every 5 days, in glazed pots. The seedlings, in groups of 5, were: (1) started in complete nutrient solution, allowed to grow for various lengths of time and transferred to incomplete nutrient solutions (lacking N, P, or K); (2) started in incomplete solutions and then transferred to complete solutions; or (3) grown in incomplete solutions throughout the entire period,

except for 20 days, at different periods of growth, when they received complete solution. Controls were given the complete solution throughout the growing period. The experiment lasted from the date of germination (29 May for *L. leptolepis*, 5 June for *T. dolabrata*) until October. The following results were obtained for *L. leptolepis*: (a) Seedlings made normal growth when supplied with N for 70 days after transplanting. Those on nutrient solutions lacking N for 20 days after transplanting, were below normal. The seedlings grown in incomplete solutions responded best to the supply of N for the 20 days from 8 to 28 July for height growth, and the 20-day period from 23 June, 8 July and 23 July for weight growth. (b) Seedlings supplied with P for 40 days after transplanting made normal growth; those deprived of P for 45 days after germination made normal root but poor top growth. Those grown in incomplete solutions responded best to the supply of P from 8 to 28 July. (c) Seedlings supplied with K for 40 days after transplanting made normal top growth, but even those supplied with K for 70 days made less root growth than the controls. Absence of K for 45 days after germination did not affect growth. The seedlings in incomplete solutions responded best to the supply of K from 23 July to 12 August. The following results were obtained for *T. dolabrata:* (a) Seedlings made normal growth when supplied with N for 40 days after transplanting. Growth was little affected by deprivation of N for 40 days after germination. Seedlings on incomplete solutions responded best to the supply of N during the last 10 days of July. (b) Seedlings supplied with P for 20 days after transplanting, made normal growth and better growth than those supplied with P for any other 20-day period. Absence of P for 40 days after germination did not affect growth. (c) Seedlings made normal weight growth when supplied with K for 20 days after transplanting, but to make normal height growth needed a supply of K for 70 days. Absence of K for 40 days after germination did not affect growth. Seedlings made more weight growth when K was supplied from 4 to 24 August. The plan of the experiment is drawn in diagrams, and the results are presented in graphs, tables, and photographs, all with English captions.

Sato, Y. and K. Muto 493

1951 (Factors affecting the resistance to cold of tree seedlings II Effect of potassium salts). Res. Bull. exp. For. Hokkaido 15: 81-96. (Japanese w/English summary) fa

Seedlings of *Picea jezoensis*, *P. abies*, *Abies sachalinensis*, *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Pinus densiflora*, *P. thunbergii*, and *Cinnamomum camphora*, were grown in nutrient solutions containing different amounts of K. To test the effect of the supply of K at different periods of growth, some seedlings were grown in solutions containing no K, and K added after 20 days at different stages. After treatment of 2-3 months, the osmotic pressure of the seedlings was measured and they were transplanted into quartz sand and exposed to low temperature. The following results were obtained: (1) All the species except *P. densiflora* showed more cold resistance with the higher amounts of K in the nutrient solution. (2) *C. japonica* showed more resistance to cold when K was supplied in the early stage of growth, *P. jezoenis*, *C. obtusa*, *P. densiflora* and *C. camphora* when it was supplied at the middle stage. (3) High osmotic pressure was related to the supply of large amounts of K. Osmotic pressure was higher in seedlings with K supplied at the middle stage of growth.

Sato, Y. and K. Muto 494

1953 (Fundamental studies on the nutritional physiology of *Picea* spp. 1). Res. Bull. exp. For. Hokkaido 16: 206-227. (Japanese w/English summary) faA

Seeds of *P. jezoensis*, *P. glehnii*, and *P. abies* were sown in vessels with quartz sand on 3 May 1952, nutrient solutions were supplied from 25 May and the seedlings were transplanted to water culture in pots containing nutrient solutions on 11 June. Controls were given the complete nutrient solution throughout and other seedlings were given at different periods incomplete solutions lacking either N, P, or K. The following results were obtained: (1) *P. jezoensis:* (a) growth was normal, as compared with the controls, when N or P was withheld after 95 days or K after 80 days, on the complete solution: (b) lack of N or K for 20 days or of P for 35 days at the beginning of the culture, did not affect growth; (c) seedlings supplied with N or P for 20 days after 14 July or with K for 20 days after 14 June or 13 August, made more growth than when the nutrients were supplied for a period of 20 days at other times during the experiment. (2) *P. glehnii*: (a) seedlings made normal growth when N, P, or K was withheld after 95 days, on the complete solution; (b) lack of N or P for 20 days or of K for 35 days at the beginning of culture, did not affect growth; (c) seedlings responded best to the presence of N or P for 20-day periods from

14 June to 18 August and to K from 14 June to 2 September. (3) *P. abies:* (a) growth was normal when N was withheld after 95 days and P or K after 80 days; (b) lack of N for the first 35 and of P or K for 35 days or more, did not affect growth; (c) the most effective use of all three elements was made during the 20 days after 19 July.

SCHAIRER, E. 495

1956 Bodenkundliches über forstliche Düngungsversuche im Schwarzwald und in Oberschwaben (Experiments with forest fertilizers in reference to soil conditions in the Black Forest and Oberschwaben). Phosphorsäure 16: 1.

SCHNEIDER, B. 496

1952 Erfahrungen mit Kalk-und Gründüngungen auf podsolierten Waldböden (Experiences with liming and green manuring on podzolized forest soils). Forstarchiv 23: 153-158. fa

In liming trials at Burgsteinfurth in N.W. Germany, over-liming with CaO before sowing caused severe growth disturbances and mass dying in sowings of Scots pine. Good results have been achieved with 80% CaO applied at a rate of 2500-3000 kg./ha. for the activation of raw humus under old pine and on clear fellings, and 1500-2000 kg./ha. for strip sowings or plantings of pine. Norway spruce and larch will tolerate twice these quantities. For activating deep beech raw humus at least 6000 kg./ha. are needed. Some figures are included from experiments to show the increase of the bacterial and the decrease of the fungal population in samples of beech and Scots pine + beech raw humus after liming, under laboratory conditions. In trials with perennial lupine (*Lupinus polyphyllus*) plus liming, too high an admixture of lupine resulted in abnormal rooting habit (often the failure of tap root development) and poor stem form in some pine plantations, attributed to excess of N in the litter. The author is now trying 1-m. squares sown with lupine, at 4-m. triangular spacing with pine in the interspaces, and also 4- to 6-m. squares with a 40-cm. border of sown lupine, the interior of the square being planted with pine.

SCHODL 497

1951 Auszug aus den Vorschlägen des Regierungsforstamtes Oberpfalz (Summary of the amelioration proposals of the

State forest office, Upper Palatinate). Mitt. StForstverw. Bayern. 26: 127-149. fa

These outline the further work needed for the improvement of degenerated stands and soils in the Upper Palatinate.

Schonnamsgruber, N. 498

1955 Studien über die Phosphataushalt von jungen Holzpflanzen insbesondere von Pappeln (Studies concerning the phosphate economy of young woody plants, particularly poplar). Mitt. württemb. forstl. VersAnst. 12 (2). 66 pp.

Schwappach, A. 499

1916 Forstdüngung (Forest fertilization). J. Neumann, Neudamn.

Scott, D. R. M. 500

1952 Growth of hybrid aspen in pot cultures of the litter of forest plants. J. For. 50: 107-108. faA

An experiment was set up to determine the relative ability of the litter of several tree and subordinate vegetation species typical of the forests of NW Connecticut to supply plant nutrients. Hybrid aspen cuttings of a single clone were planted in pots in mixtures of various types of litter and silica sand, and grown for 6 months. The litter of the subordinate forest vegetation generally proved superior to the litter of tree species. There appeared to be little correlation between the content of nutrient elements (N not measured) in the litter from various species, and the effects of the litter on the growth of hybrid aspen.

Semakin, K. S. 501

1936 (The influence of various methods of plant hardening on their drought resistance under different conditions of mineral nutrition). Acta Inst. bot. Acad. Sci. USSR. IV: 2: 225-270. (Russian)

Semakin, K. S. 502

1938 (The influence of ash elements and nitrogen on drought and cold resistance in plants). Acta Inst. bot. Acad. Sci. USSR. IV: 3: 213-240. (Russian w/English summary)

Shcherbakov, A. P. and E. N. Mishustin 503

1950 a (Nutritional conditions as a means of hastening the growth of oak seedlings and the development of mycorrhizae on their roots). Agrobiology 5: 121-127. (Russian)

Shcherbakov, A. P. 504

1950 b (Some peculiarities of the ash content of two year seedlings of coniferous species). Dokl. obsch. Sobr. Ak. Nauk S.S.S.R. 71: 1143-1146. (Russian) fa

Deals with fertilizer trials in 1949 on grey forest soils in the Tellerman experimental forest, Voronezh Province. The fertilizers were dug in to a depth of not less than 20-25 cm., several days before sowing. Best results were given by applications of N, P_2O_5, and K_2O at respectively 20, 180, and 30 kg./ha. High P_2O_5 hastened germination of the acorns, increased the organic matter content of the seedlings, improved root and mycorrhiza development and increased the soil microflora population. Additional N, with P_2O_5 and K_2O held at low level, retarded germination, decreased seedling growth, and reduced mycorrhizae and the soil microflora. Results are shown in tables and graphs.

Shibamoto, T. 505

1956 (Fertilizing forest lands). 26 pp. Forest and Estate Mutual Foundation, Tokyo. (Japanese)

*Translated and published by Nitrogen Division, Allied Chemical and Dye Corporation, New York.

Shibamoto, T., S. Nakajima, and T. Inoue 506

1955 (Studies on the soil amelioration of the denuded forest land about Seto in Aichi Prefecture. I. On the effect of horizontal ditch ploughing and fertilizing on the growth of *Pinus thunbergii* Parl.). Bull. Tokyo Univ. For. 48: 153-168. (Japanese w/English summary) Ba

Nursery grown seedlings were planted in pots on hill-side plots, and the effects of various means of amelioration on growth and on inorganic content of needles were compared. Horizontally ploughed ditch, which was set up along the contour every 1 m. of altitude and covered with rice straw at the rate of 2 kg. per 1 m. of ditch, was effective in promoting the growth of planted trees, especially

when N-P-K fertilizer was used. The compost favored root growth, but use of chemical fertilizers in addition was desirable. Fused magnesium phosphate was as effective as superphosphate. The effect of fertilization on diameter growth became evident in the year of fertilization, and from the next year onward, the effect was seen on both diameter and height growth.

SHIBATA, N., M. ONO, AND H. HOSHINO 507

1951 (Trials of fertilizers in the Suchi nursery. 2, Effects of Mn, Mg, Zn, and B on the growth of seedlings of Sugi and Hinoki). Trans. Jap. For. Soc. 59: 88-90. (Japanese w/ English summary) faA

The use of sulphates of Mn, Mg, Zn, or B or boric acid, with a fertilizer containing N, P_2O_5, K_2O and CaO, had a remarkable effect on seedling growth of *Cryptomeria japonica* and *Chamaecyparis obtusa*. The use of these compounds without the fertilizer had little effect. Recommendations are made on rates of application.

SHIRLEY, H. L. AND L. J. MEULI 508

1938 Influence of foliage sprays on drought resistance of conifers. Plant Physiol. 13: 399-406. BaA

Four foliage sprays consisting of water emulsions of (1) beeswax, (2) equal parts of beeswax and parowax, (3) rubber soln., (4) hydrowax liquid N, were applied to seedlings of *Pinus resinosa*, *P. strobus*, and *Picea glauca*. Drought resistance was determined by testing in a special drought chamber, and by planting on exposed, sandy sites. None of the sprays used improved resistance to drought. Preliminary tests with a 5th spray also gave negative results.

SHIRLEY, H. L. AND L. J. MEULI 509

1939 The influence of soil nutrients on drought resistance of two-year-old red pine. Amer. J. Bot. 26: 355-360. fa

Nursery and pot cultures of *Pinus resinosa* seedlings in their second growing season were supplied with varying amounts of nitrogen, phosphate, and water. At the end of the season tests were carried out in "drought machines" under controlled conditions. Drought resistance was assessed in the pot cultures by the moisture content of seedlings after three days' exposure to drought; in the nursery cultures the length of survival under drought conditions

was taken as an index. Both types of culture showed that drought resistance regularly fell with increase in the nitrogen supply. The effect of phosphate supply varied with the amount of nitrogen present. If nitrogen was absent, increase in the phosphate supply gave improved drought resistance; in the presence of nitrogen the same tendency was noticeable, but the optimum P:N ratio was not determined. The influence of phosphate supply was not statistically significant in the nursery cultures owing probably to an adequate natural supply. No demonstrable effect of the watering regime could be found in the pot cultures; in the nursery, however, plants watered daily were less resistant than those watered at three day intervals if nitrogen was absent. When nitrogen was supplied the effect was masked, probably because heavy watering would leach out nitrogen from the soil and thus favor the heavily watered seedlings to some extent. In both series of tests small seedlings appeared to be more resistant than large, but even after correction for size, the order of results of different treatments remained unaltered. The ratio of root to top showed only a rough correlation with drought resistance. The investigation shows that resistance depends upon a balance of nutrients as well as upon the concentration of nitrogen alone; further research is therefore needed to determine the optimum nutrient regime for producing plants that are at the same time normal-sized and drought-resistant.

Siggers, P. V. 510

1944 The brown spot needle blight of pine seedlings. Tech. Bull. U.S. Dep. Agric. 870. 36 pp. faA

The dwarfing effect of brown spot disease on the early growth rate of longleaf pine (*Pinus palustris*) seedlings was studied under natural conditions by controlling the disease with fungicides over a period of years. The detrimental effect of severe attacks of the disease on survival of planted seedlings was indicated by greater mortality among unsprayed lots of seedlings in the older demonstration area. At least three successive annual defoliations were required to weaken a seedling sufficiently to cause death. The longer a seedling stand remains dwarfed by the disease the greater the hazard that the stand will be depleted by other adverse factors of the environment. The growth capacity of stunted, diseased longleaf pines can be altered by improving the chemical composition of the soil. Single fires during the dormant season greatly reduced the disease during the first season thereafter and to a lesser extent dur-

ing the second season. Spraying and soil amendments, except under nursery conditions, do not appear economically feasible for controling brown spot disease.

SIMMONDS, N. W. 511

1951 Notes on field management at the Botany Department of the Imperial College of Tropical Agriculture, Trinidad. Trop. Agriculture, Trin. 28: 70.75. fa

The work of the Department included experiments with *Gliricidia seplum* as a shade tree, and notes on its propagation and tending are presented. If the trees are pollarded early in the wet season (July), and again later in November and December the plants can largely be prevented from flowering and shedding their leaves during the dry season. A method is also described of making compost from sawdust, pen manure, fresh Elephant or Guatemala grass and NH_4 sulphamate.

SIMONART, P., AND A. HUYGH 512

1953 Over de microbiologie in de Kempische bosgronden (Microbiology of forest soils in the Campine). Agricultura, Louvain, Ser. 2, 1: 33-51. (Flemish w/French, German and English summaries). fa

The microbial population of soils under oak, pine, and heathland in spring, summer, and autumn was studied by the plate method and by direct microscopic count. Physical and chemical characteristics of the soil samples was also determined. The bacterial population was always highest under oak, that of mold fungi under pine. The heathland soil was the most subject to seasonal fluctuations, having its highest content of microorganisms in summer, and, as separate measurements showed, to fluctuations in soil temperature in heathland soils. The number of organisms decreased with increasing depth, except at 20-30 cm., where the number was smaller than in the 30-40 or 50-60 cm. layers. Respirometric tests showed relationships between the respiration coefficient and number of living microorganisms, humus content and cation exchange capacity of the soil. In pine stands the number of microorganisms increased with application of $CaCO_3$, but was not affected by applications of P fertilizers. The presence of a small percent of oak among the pine also increased the number of microorganisms.

Smith, L. 513

1925 Gødningsforsøg ved nyanlaeg of skov paa Midtjydsk Hedejord (Use of fertilizers in establishing forests on the heathland of Middle Jutland). Forstl. Forsøksv. Danm. 9: 1-160. (Danish w/French summary) Ba

Lime, potash, and basic cinder have not proven desirable fertilizers for oak on heath soils. Cultivation and nurse crops of *Pinus montana*, lupine, and *Spartium scoparium* have proven the best practice. Seed of local trees should be used wherever possible.

Smith, L. 514

1927 Gødningsforsøg paa Hedejord (Use of fertilizers on heath soils). Forstl. Forsøgsv. Danm. 9: 161-182. (Danish w/ French summary) Ba

A supplemental report is made on the use of lime, potash, and basic cinder as fertilizers together with soiling crops. Soiling crops and nurse crops proved most desirable in reclaiming heath soils, using oak, Norway spruce, and noble fir as planting stock. Nurse crops of white alder and *Pinus montana* are recommended.

Smith, M. E. 515

1943 Micronutrients essential for the growth of *Pinus radiata*. Aust. For. 7: 22-27. Ba

Pinus radiata seedlings were grown in culture solutions deficient in Zn, Cu, Mo, Bb and B. Mn-deficiency led to severe injury and less than ½ the height, after five months, of seedlings supplied with 0.1 mg. Mn per liter. Lack of Cu resulted in less severe but distinctive symptoms, which developed more slowly. Plants without Zn suffered severe injury and were only about ⅛ as tall after five months as those in solution with 0.1 and 0.5 mg. Zn per liter. With B-deficiency, injury developed slowly but was characteristic and quite severe. Plants grown without Mo grew well, at least for five months, but there were indications of a gradual disturbance of their metabolism.

Smith, M. E. and N. S. Bayliss 516

1942 The necessity of zinc for *Pinus radiata*. Plant Physiol. 17: 303-310. fa

Seedlings of *Pinus radiata* grown in zinc-free culture solutions showed deficiency symptoms in three to four months. Attempts at

mycorrhizal inoculation were unsuccessful. The symptoms of zinc deficiency are described.

Sørensen, H. 517

1943 Gødningsforsøg i planteskolekulturer (Fertilizer trials in nurseries). Tidsskr. Planteavl. 48: 299-317. (Danish)

Southern Forest Experiment Station 518

1953 Fertilizing longleaf seedlings with urea nitrogen in south Mississippi. Rep. sth. For. Exp. Sta. 1952: 42. fa

Natural longleaf pine seedlings from the 1948 seed crop, growing on a dry sandy site, were sprayed four times in 1951 and five times in 1952 with urea nitrogen (Nu Green) and Bordeaux mixture alone or in combination. Urea N was applied at a rate of 25 lbs. N/acre per application. At the end of two growing seasons untreated seedlings and those sprayed with urea N alone had both grown an average of 0.06 in. in root-collar diameter, and those sprayed with Bordeaux mixture kept brown-spot defoliation down to 4% in December 1952 as against 54% for unsprayed seedlings.

Southern Forest Experiment Station 519

1954 Fertilizer fails to stimulate longleaf height growth in central Louisiana. Rep. sth. For. Exp. Sta. 1953: 19. L

Fertilization of planted longleaf pine seedlings, using superphosphate, muriate of potash, cottonseed meal and ammonium nitrate at the rate of 55 g. of mixture applied in a hole about 4 inches from each planted seedling, has not stimulated early height growth near Alexandria, Louisiana. In fact, by stimulating the growth of grass and weeds, the fertilizer has actually reduced the percent of seedlings that are emerging from the grass stage. Where herbaceous competition had been reduced the fertilizer did seem to stimulate height growth.

Southern Forest Experiment Station 520

1956 Improved planting techniques sought—nursery and field. Rep. sth. For. Exp. Sta. 1955: 21-24. L

Winter fertilization of seedbeds just prior to lifting has failed to improve the survival and growth of loblolly seedlings outplanted on adverse north Mississippi sites. The fertilizer was a combination

of 160 lbs. of N and 200 lbs. of K_2O, the whole applied in three equal doses at 4 day intervals about 5 weeks before lifting time. The treatment reduced first year survival and had no apparent effect on first year height growth.

STARR, G. H. 521

1940 Treating deciduous trees for chlorosis. Phytopathology 30: 23. fa

Chlorotic deciduous trees in Wyoming have been treated with ferric phosphate, injected into holes bored in the trunks. Results are highly satisfactory, but the optimum dose has not yet been determined.

STEINBAUER, G. P. 522

1932 Growth of tree seedlings in relation to light intensity and concentration of nutrient solution. Plant Physiol. 7: 742-745. Ba

Experiments with *Fraxinus pennsylvanica* showed that if the supply of nutrients was sufficient to satisfy the needs of the plant the minimum light requirement was not lowered by increasing the nutrient supply. A response to increased concentration of nutrients could be obtained at higher light intensities.

STEWART, A. B. 523

1936 Some soil problems in forest nurseries. Scot. For. J. 50: 86-92.

STEWART, A. B. 524

1954 Gödsling i skogsträdsplantskolor i Skottland (Fertilization in forest tree nurseries in Scotland). Växt-närings-Nytt 10: 25-30. (Swedish)

STIRLING MAXWELL, SIR J. 525

1925 On the use of manures in peat planting. Trans. R. Scot. arb. Soc. 39: 103-109.

STOATE, T. N. 526

1950 Nutrition of the pine. Bull. For. Bur. Aust. 30: 61 pp. A

The report covers investigations extending over nearly a quarter of a century, into the nutrition of the pine in Western Australia

and the successful establishment and growth of pine plantations has been made possible on poor and infertile soils formerly regarded as unsuitable for the purpose.

Standards of relative soil fertility for pine growing have been developed on the basis of their phosphate content.

The morphological characteristics of the symptoms of a number of disorders of both *Pinus radiata* and *Pinus pinaster* are described.

The Leiria strain of *Pinus pinaster* is of great importance, not only because of its better form and faster growth, but because it appears to be better adapted to the poor coastal sands.

The history is traced of the early trials with animal manures, phosphatic and nitrogenous fertilizers and the trace elements commencing with ferrous sulphate and leading finally to the widespread use of superphosphate and zinc. Superphosphate is a corrective and preventive in the disorders of *Pinus pinaster* on the poor sands of the coastal plain and also, on some plantations at least, of the group of disorders leading from "yellowing" to "spindle stands" and "dead top" in *Pinus radiata*. Zinc is a corrective and preventive of the group of disorders from rosetting to die-back which are characterised by a die-back of the leader and a tendency to broom-bush condition in both *P. radiata* and *P. pinaster*. (Very heavy dressings of superphosphate have corrected some of these disorders on some soils.) In a few plantations where the Myalup disorder in *Pinus pinaster* develops, either element may be used.

In South Australia, spraying with zinc has been absorbed into standard practice in the establishment of *P. radiata* plantations in the south-east. Striking responses to superphosphate have been shown by both *P. radiata* and *P. pinaster* in certain plantations in the Mt. Lofty Ranges.

It appears that the effect of a corrective treatment is lasting if it can induce sufficient growth to bring about a closing of the canopy and complete control of the site. Satisfactory growth has been maintained for 16 years without further applications of fertilizer. An interesting discovery has been the good development of natural regeneration of *Pinus radiata* on a fire-killed area previously sprayed with zinc. This contrasts with the disorder condition in the regrowth a few feet away on unsprayed land.

Indications of the adaptation of the pine to a hitherto very unfavourable site have been shown by the colonising of adjoining blank areas with regeneration from trees grown with superphosphate, and this if continued would have far-reaching results.

There are still puzzling problems in pine nutrition to be dealt with and the investigations must be continued.

STOATE, T. N. 527

1955 Some aspect of forest establishment and growth. Mac Millan Lect. For. Univ. B.C. 1955. 13 pp. GKV

Formerly it was thought that the physical properties of the soil were of the greater importance in forestry, although the chemical properties have long been studied in agricultural practice. It is well known in agriculture that crops grown on different soils differ greatly not only in yields, but also in resistance to disease. The soils themselves differ greatly in the content of elements essential to plants.

Particularly in the growing of exotic trees in plantations, the forester is more closely approaching agriculture where use is made of cultivation and artificial fertilizers.

Some of the best illustrations of the close relationship of soil deficiencies to tree disorders are to be found in Australia and New Zealand where the results suggest a wide field for study.

The unsatisfactory behaviour of early plantings in Western Australia revealed the need for investigation into the causes of sickness in pine stands and the possibility of remedial measures being developed.

The lead given by agriculture and horticulture in Southern Australia where all field crops show a response to superphosphate was followed. The commercial development of 3000 acres of pine plantations on sand on the coast of Western Australia is believed to be unique in that the growth is entirely dependent upon superphosphate. Without the fertilizer the trees would have stagnated or died at a height of 3 or 4 feet. The early stands of *P. pinaster* have now reached a height of more than 50 feet, supporting a small sawmill with thinnings.

Superphosphate unfortunately had little effect in several types of disorders and no effect at all in some. Cultivation had long produced beneficial effects on the edges of plantations, and improvement which at one time was attributed soley to additional spacing. Combinations of superphosphate and cultivation caused improvements in most cases, but were costly and on many sites impracticable of application because of logs, rock and contour.

Success following early failure attended trials with the trace of minor elements. Zinc is a corrective and preventive of the group

of disorders ranging from "rosetting" to die-back" which frequently result in a dying of the leader in *Pinus radiata*. In such cases zinc can be given to the tree in almost any manner and still be effective. It can be applied to the ground as water-soluble salts or oxides in the solid form, or solutions containing zinc may be injected into or sprayed upon the tree.

With some species disordered trees may be restored to vigorous growth by driving a zinc-coated nail into the trunk. Probably of all the effects, the return to normal growth of stunted trees through which a wire netting vermin-proof fence had been erected, is the most interesting.

In South Australia there has been greater opportunity for the commercial use of fertilizer treatments in *P. radiata* because of the large plantations of that species which have been established there. Early experimental work determined the beneficial effect of zinc and phosphate in correcting certain disorders of the pine. In the southeast of that state zinc is now used as a step in standard establishment practice, not as a corrective, but as a preventive of a disorder. There low "die-back" causes a malformation in a number of trees whose commercial value, in extreme cases, is entirely lost through a multiplication of leaders. The application of zinc at an early age by spraying with a 2½% solution of zinc sulphate completely prevents this occurring and enables the site to produce a higher volume. Practical results are a yield of 1000 to 1250 cu. ft. from thinnings at 14 years from zinc-treated areas, while untreated controls may not provide a thinning yield under twice that age.

It is possible by the application of inorganic salts to increase to a certain extent in a soil content of elements essential to some plant growth, and with a view to supplying deficiencies in the soil and providing for the specific demands of various agricultural crops, mixed fertilizers of a variety of types have been prepared commercially. The results which have been obtained so far in forestry have in general been secured with unbalanced fertilizers and usually with only one element.

STOATE, T. N. AND B. H. BEDNALL 528

1953 Later disorders in pine stands in South and Western Australia. Leafl. For. Bur., Canberra 66. 20 pp.

STOEKELER, J. H. 529

1933 The use of fertilizers in the forest nursery. For. Wrkr. U. S. 9: 8-9.

STOEKELER, J. N. 530

1940 Effect of liquid fertilizers on nursery stock. Tech. Note Lake St. For. Exp. Sta. 162, 1 p. A

Treatment of 2-0 red pine beds at Rhinelander, Wisconsin, with liquid fertilizer in the form of 15-30-15 nitrophoska (3 levels) or liquid humate (3 levels) resulted in consistent improvement in the percent of plantable stock, in average green weight, and a slight improvement in field survival. One of the better treatments was 400 pounds per acre of nitrophoska applied at the rate of 10 quarts of solution per 50 square feet of bed. It increased plantable stock by 30 percent, green weight by 76 percent, first-year survival by 8.8 percent, and second-year survival by 4.2 percent.

STOECKELER, J. H. 531

1940 Fertilized nursery stock shows increased nursery production and higher field survival. Tech. Notes Lake St. For. Exp. Sta. 169. 1 p. A

Fertilization of 1-0 jack pine beds in a Wisconsin nursery with 20 tons of dry peat and 1,160 pounds of a complete N-P-K fertilizer per acre gave a 40-percent increase in plantable stock and an increase in second-year field survival of 7.4 percent compared with untreated stock. Each 10 percent increase in plantable stock was worth $150, while costs of fertilizing were only $30 to $80 per acre.

STOECKELER, J. H. 532

1945 Nutrients in duff and humus layers increase growth of forest plantations. Tech. Note Lake St. For. Exp. Sta. 266, 1 p. A

Plantations of red pine and black spruce in the Lake States often show 50 percent greater height growth at end of 2 or 3 years when planted on disked areas or on turned under soil compared with those planted in the bottom of a furrow. In the latter case the most nutrient-rich layer of the soil has been pushed out of the immediate reach of recently planted trees. If disked or turned under the nutrients in the organic layers are near or in contact with the root system of the newly planted tree.

A chemical analysis of the organic layers of a typical aspen stand of the type often underplanted with conifers showed markedly higher nutrient content of the duff (F) and humus (H) layers

than the underlying leached A2 horizon. The contrast was especially striking in organic matter, total nitrogen, replaceable potash, and replaceable calcium. These were anywhere from 15 to 46 times as high in the F and H layers as in the A2.

STOECKELER, J. H. 533

1949 Correction of soil acidity in conifer nurseries. Tech. Note Lake St. For. Exp. Sta. 319, 1 p. A

Excessive soil acidity in a northern Wisconsin nursery caused by repeated use of sulphuric acid as a fungicide and to acid peats used as a source of organic matter resulted in malnutritional symptoms of 2-0 red pine and 1-0 jack pine. The symptom was a bright yellow-gold color on the outer one-half to one-fourth of the needles.

Dolomitic limestone applied at the rate of 1,500 pounds per acre raked into the beds between seedling drills resulted in a marked improvement inside of 10 weeks as judged by the virtual disappearance of yellow tipping and an increase in average fresh weight per seedlings. In untreated, off-color areas, the soil pH was 4.11. In beds treated with the above specified amount of limestone it was 5.25 or an increase of 1.14 in pH due to soil treatment.

STOECKELER, J. H. 534

1953 Lupines as a nursery soil improvement crop. Tech. Notes Lake St. For. Exp. Sta. 395. 1 p. fa

A number of *Lupinus* spp. were sown on 13 June, 1951, and measurements made in September to show average height, oven-dry weight/acre and N in entire crop/acre on limed and unlimed plots. Further tests in 1952 showed the superiority over other species of *L. angustifolius* especially in colder areas and higher altitudes.

STOECKELER, J. H. AND G. W. JONES 535

1956 Forestry nursery practice in the Lake States. Agric. Handbook 375 pp. (In print). A

This monograph cites the chief value of fertilizer in the nursery as being the increase in per cent of plantable stock. In the case of 2-0 red pine, each 10 per cent increase in plantable stock is worth about $375 per acre.

Extreme deficiency of nutrients such as phosphate can cause outright starvation and mortality in the nursery.

Foliar symptoms of malnutrition are listed for N, P, K, Fe, Ca, and Mg and corrective measures are suggested.

Field followup of about 139,000 trees from a large number of nursery fertility experiments show average field survival gains in the range of 4 to 14 percent of 1- to 3-year-old plantings for the better fertilizer treatments. Average height showed very minor differences at end of 5 to 8 years.

STONE, E. L. 536

1940 Calcium requirements of some deciduous seedlings. M.S. Thesis. Univ. Wis., Madison.

STONE, E. L. 537

1950 Some effects of mycorrhizae on the phosphorous nutrition of Monterey pine seedlings. Proc. Soil Sci. Soc. Amer. 14: 340-345. faA

Pot culture studies with *Pinus radiata* grown in a synthetic soil containing ground phosphatic minerals, failed to demonstrate any effect of mycorrhizae on P uptake by the seedlings. Similar cultures of pine on O'Neill sandy loam and Carrington silt loam showed that mycorrhizal infection was followed by accumulation of P by the plant and resumption of normal growth. Nonmycorrhizal seedlings failed to accumulate any considerable quantity of P from untreated (i.e. without additional P) soils, but, on the Carrington soil, grew satisfactorily when P fertilizers were supplied. It is concluded that at least much of the mycorrhizal response in pine can be attributed to improved P nutrition.

STONE, E. L. 538

1953 Magnesium deficiency in some northeastern pines. Proc. Soil Sci. Soc. Amer. 17: 297-300. aA

Magnesium deficiency of *Pinus resinosa*, *P. strobus* and *P. banksiana* was studied in young forest plantations on light textured soils bordering the western and southwestern margins of the Adirondack province of New York.

The most conspicuous symptom of deficiency was a bright yellow discoloration of the tips of the current season's needles, appearing in the fall and affecting the upper part of the tree most strongly. When the deficiency was severe, the chlorosis was follow-

ed by death of the needle tips or premature loss of foliage. Gross reductions in shoot growth and needle length occurred only under extreme deficiency or when lack of magnesium was accompanied by potassium deficiency.

In *P. resinosa* the appearance of deficiency symptoms was usually associated with magnesium contents less than .16% of the oven-dry weight of mature first year foliage; with less than about .13% symptoms were severe. Fertilization with magnesium sulfate at rates of 20 to 50 lbs. Mg/acre eliminated or reduced the symptoms after a lapse of at least a year.

Fertilization of deficient trees with magnesium sulfate resulted in increased height growth over a period of at least three years. In two instances this increase was shown to be additive to that due to potassium, without evidence of significant interaction.

STONE, E. L. 539

1955 Observations on forest fertilization in Europe. Proc. nat. Comm. Fert. Appl. 31: 81-87.

STONE, E. L. AND C. MCAULIFFE 540

1954 On the sources of soil phosphorus absorbed by mycorrhizal pines. Science 120: 946-948. a

Pine seedlings (grown in nutrient solution without P) and/or rye grass were grown in containers on loam soil treated with radioactive KH_2PO_4 and inoculated with untreated and autoclaved segments of mycorrhizal pine root. While there was little or no response to P by seedlings with no or few mycorrhiza at harvest, increased total P in tops of mycorrhizal pine was in a linear relationship with the uptake of inorganic P added. The similar trend in the uptake of added and native P by both grass and mycorrhizal seedlings indicated that roots of the latter had no special capacity to utilize organic P in the soil.

STRONG, F. C. 541

1944 A study of calcium chloride injury to roadside trees. Quart. Bull. Mich. agric. Exp. Sta. 27: 209-224. Ba

Field studies of injured and dead trees located on the sides of gravelled roads which had been treated with $CaCl_2$ as a dust palliative indicated that the chemical may cause serious injury and even

death in locations where the water flowing off the highway is impounded in depressions. Minor injury could be easily confused with drought damage, and $CaCl_2$ injury was accentuated by drought conditions, but severe $CaCl_2$ injury produced characteristic symptoms. Pot studies in the greenhouse showed that trees may be readily killed by $CaCl_2$ applications to the soil and that different species vary in their tolerance. NaCl was found much more toxic to elm and white pine than was $CaCl_2$. Tree roots did not appear to be readily injured by $CaCl_2$ as were the leaves where the salt accumulates. Where $CaCl_2$ was applied directly to the leaves to a direct mixture, there was a brown spotting rather than scorching.

Süchting, H. 542

1939 Untersuchungen über die Ernährungsverhältnisse des Waldes. IV. Prüfung ausgewählter Waldböden auf Nährstofflieferung durch Vegetationsversuche mit Lärche,Kiefer und Fichte sowie auf Nährstofflöslichkeit durch chemische Untersuchungsmethoden (Studies on forest nutrition. IV. Examination of nutrient supply of selected forest soils by growth experiments with larch, pine and spruce and of the nutrient solubility by chemical methods). Bodenk. u. PflErnähr. 13: 73-117. fa

The fertility of nine different forest soils and the effect on growth and nutrient absorption of separate and combined additions of Ca, K, P, and N, were investigated in vegetation experiments which differed from Neubauer's usual procedure mainly in that larch, pine, and spruce were employed as test plants instead of rye (which does not behave normally in acid forest soils), and were allowed to grow during a whole summer. Technique and results of these experiments are discussed. A distinction is drawn between "simple" deficiency where fertilizer addition increases growth as expressed in weight but does not increase the relative amount of nutrient contained in the plant, and "intensified" deficiency where both growth and nutrient content are increased by manuring. In general, fertility data from the vegetation experiments corresponded well with results of chemical analyses.

Süchting, H. 543

1940 a Praktische Winke für die Kalkdüngung (Practical hints on liming). Forstarchiv 16: 291-296. fa

Lime may be applied as the raw products of limestone quarries and marl pits, as commercially processed marl (about 80% $CaCO_3$), or as burnt lime (CaO). The last-named should be applied during cool, moist weather in autumn and early winter, the other two at any time. Under certain conditions CaO has started fires. Liming may be done 5-10 years before or 6-8 years after the new stand is established.

Süchting, H. 544

1940 b Untersuchungen über die Ernährungsverhältnisse des Waldes. V. Vergleichende Prüfung von Waldböden auf Nährstofflieferung durch Vegetationsversuche mit Lärche, Kiefer und Fichte sowie auf Nährstofflöslichkeit durch chemische Untersuchungsmethoden (Studies on forest nutrition. V. Comparative tests on the nutrient supply of forest soils by growth experiments with larch, pine and spruce and on the nutrient solubility by chemical methods). Bodenk. u. PflErnähr. 19: 125-160.

The present experiments were designed primarily to afford a statistical test and comparison, using very different types of soil, of the methods used to investigate the nutrient conditions in forest soils. The results obtained showed good correspondence with those of the first experiments made in 1937, and the vegetation test, with certain slight modifications, is approved as a standard method. Chemical determinations of the capacity of the plant to take up K from the soil agreed well with the results of the vegetation test as in the 1937 experiments. Results from chemical methods of determining P_2O_5 uptake also agreed with those of previous years. The fixation of P_2O_5 applied as fertilizers was shown to vary greatly in different soils. General nutrient deficiency was so marked in nearly all the soils that the best growth could be obtained only by complete fertilizing with Ca, K, P_2O_5, and N. All the soils were deficient in K and P_2O_5 and most of them in N.

Süchting, H. 545

1941 Untersuchungen über die Ernährungsverhältnisse des Waldes. VI. Vergleichende Prüfungen von A_0-Humusartenals Nährstofflieferung durch Vegetationsversuche mit Kiefer und Fichte sowie auf Nährstofflöslichkeit vermittels chemischer Untersuchungsmethoden (Studies on forest nu-

trition. VI. Comparative tests of A_0 humus types for nutrient supply by growth experiments with pine and spruce and for nutrient solubility by chemical methods of investigation). Bodenk. u. PflErnähr. 24: 87-112. fa

The experiments were designed to furnish data on K, Ca, P_2O_5, and N in the humus, the ability of the plant to use these nutrients, the effect of pH, and the effect of changing the pH by liming. The acid and nutrient status of the humus types is shown to depend largely upon the chemical character of the mineral soil and not on the tree species from which the humus is derived. Liming was found to be effective only on humus soils with a pH of 3 or less, and in this connection the possible effect of Al as a toxic agent is discussed. The uptake of K from humus is very high, and more is taken up when the plants are fertilized. Pine responded better than spruce to K fertilizer. Plants fertilized with K remained free from attack by grey mold. P_2O_5 uptake was also great in the humus types examined. Further study is needed on the status of N in the humus. In order to make the root-soluble nutrients of the A_0 humus sufficient for the trees, the humus must be mixed with the mineral soil; this is achieved by rain and animal activity. Data are given on the solubility of the K and P_2O_5 of the humus according to determinations made by chemical methods.

Süchting, H. 546

1943 a Amélioration de la fertilité des sols forestiers et augmentation de la production par le chaulage (Improvement of fertility of forest soils and increase of wood production by application of lime). Intersylva 3: 1-21.

Süchting, H. 547

1943 b Untersuchungen über die Ernährungsverhältnisse des Waldes IX. Einfluss der Reaktion und der Entsäuerung des Bodens durch Kalk bzw. Magnesia auf Wachstum und Nährstoffaufnahme der Lärche, Kiefer und Fichte (Studies on forest nutrition. IX. The effect of reaction and neutralization of the soil by lime or magnesia on growth and nutrient uptake of larch, pine and spruce). Bodenk. u. PflErnähr. 32: 365-375. fa

Pot experiments with larch, pine and spruce in acid soils (pH(KCl)3) showed that growth of all three increased progressive-

ly as the pH(KCl) was raised to 5 by adding either $CaCO_3$ or $MgCO_3$. Above pH(KCl) 5.4-6 growth was retarded. As the carbonates of Mg and Ca were equally effective it was concluded that the effect is a neutralizing rather than a nutrient one. Uptake of K was suppressed by heavy doses of Ca or Mg; uptake of Mg was greatly increased by Mg fertilizing and reduced by Ca fertilizing; uptake of Ca was but little affected by Mg fertilizing. P uptake depended on the reaction, and was greatest at about PH(KCl) 5; it was almost completely inhibited at pH(KCl) 5.4-6, even when the pots were heavily treated with P_2O_5. $MgCO_3$ and $CaCO_3$ had the same effect on P uptake.

Süchting, H. 548

1948 Untersuchungen über die Ernährungsverhältnisse des Waldes. X. Über die Wirkung des löslichen (reaktionsfähigen) Aluminiums zweier Waldböden auf die Kiefer (Studies on forest nutrition. X. The effect of soluble aluminum on pines in two forest soils). Z. PflErnähr. Düng. 42: 193-218. a

Soils containing over 100 mg. Al_2O_3 per 100 g. of soil are very harmful to the pine; yield decreases as high as 50% were obtained with seedlings. The absorption of Al by the pine is dependent on the content of soluble Al in the soil. Pines from Al-rich soils contained 0.2-0.3% Al_2O_3: those from Al poor soils contained 0.1-0.2%, while with soils containing no Al the content of the Al_2O_3 in the pine amounted to only 0.04-0.09%. Absorption of Al was greatest in unlimed acid soils. The Al_2O_3 content decreased with increasing lime. P_2O_5 absorption was greatly hindered by soluble Al in the soil. Addition of lime increased P_2O_5 absorption.

Süchting, H. 549

1949 a Untersuchungen über die Ernährungsverhältnisse des Waldes. XI. Über die Stickstoffdynamik der Waldböden und die Stickstoffernährung des Waldbestandes (Studies on forest nutrition. XI. The dynamics of the nitrogen in forest soils and the nitrogen nutrition of the forest stand). Z. PflErnähr. Düng. 48: 1-37. Ba

Planting experiments with oats and Scots pine, on seven types of A_0 humus of forest soils, showed that only 5-10% of the total N is easily decomposed and mineralized. The remainder is supposed

to be contained in N containing humic acids, apparently belonging to the lignin-protein complex. The small mineralizable portion is not present in true humus but is contained in accompanying substances and precursors of humus. In forest litter stored in the open, N assimilation takes place, varying in amount with the species of trees present. Nutrition of stands with N occurs primarily by biological decomposition of forest litter. In the absence of a forest stand, the soil flora, too, is insufficient, the accompanying substances are decomposed without being renewed. The supply of N to the stand by decomposition of dead roots, stub-wood, and faggots is essential. Under favorable conditions, these "harvest residues" are supposed to yield about 10-15 kg. of N per ha. per yr. The annual N supply of soil from assimiliation and the atmosphere, estimated at 7 kg. N/ha., is subject to progressive losses by the nutrient cycle of forests.

Süchting, H. 550

1949 b Kurzes Lehrbuch der Bodenkunde und Pflanzenernährung für Forstwirte und auch für Landwirte, Gärtner und Naturwissenschaftler (A short textbook of soil science and plant nutrition for the forester and also for the agriculturist, the gardner and the naturalist). xvi. + 290 pp. Landbuchverlag G.M.B.H. Hannover. fa

The elements of soil science (including biology), with a section on methods of improving the soil by draining, cultivating, fertilizing, liming, etc.

Süchting, H. 551

1950 Untersuchungen über die Ernährungsverhältnisse des Waldes. XII. Über die Wirkung von Natrium neben Kalium auf eine Holzart (Kiefer, *Pinus silvestris*) Studies on forest nutrition. XII. The effect of sodium and potassium on *Pinus silvestris*). Z. PflErnähr. Düng. 50: 165-174.

Sudan Forest Department 552

1952 Use of ammonium sulphate to stimulate growth of teak stumps. Rep. For. Dep. Sudan. Jan. 1950-June 1951: 41. fa

In one experiment the results were inconclusive, and in the other, where the $(NH_4)_2SO_4$ was put in the planting holes in direct contact with the roots, severe scorching occurred and the results were decidedly adverse.

SWITZER, G. L. AND L. E. NELSON 553

1956 The effect of fertilization on seedling weight and utilization of N, P, and K by loblolly pine (*Pinus taeda* L.) grown in the nursery. Proc. Soil Sci. Soc. Amer. 20: 404-407. A

The first-year nursery results from a study of the influence of fertility levels on the quality and field performance of loblolly pine seedlings are reported. The seedlings were grown in the nursery under 12 fertility treatments with three replications in the form of a $3 \times 2 \times 2$ factorial design; three levels of N, and 2 each of P and K. Samples of the soil and seedlings were taken at monthly intervals after sowing and analyzed. The dry weight of the seedling tops throughout the plants' development and the total dry weight of the seedlings at lifting were affected only by the nitrogen treatments, which possibly indicates that the original soil levels for available P_2O_5 and exchangeable K_2O are suitable for the nursery development of this species. The rate of uptake of nutrients expressed by the percentages in seedling tops is quite similar to the normal development of this plant part as expressed by the dry weight increase, with 50% or more of the nutrients studied being in the seedling top within 130 days after sowing. The total annual nutrient removal by loblolly pine seedlings is comparable to the annual demand of ordinary field crops. This rate of removal emphasizes the necessity of careful attention to nursery soil fertility management. The soil data also further emphasize that attention be paid to the effect of nitrogen levels on soil pH and the exchangeable cations of the soil. These preliminary results do not permit recommendation of the proper levels of nursery fertility for the satisfactory field performance of this species.

TAMM, C. O. 554

1947 Markforbättningsförsök på mager sand (Soil improvement experiments on barren sands). Medd. Skogsförskn Inst. Stockh. 36: 1-115. (Swedish w/English summary)

TAMM, C. O. 555

1951 Chemical composition of birch leaves from drained mire, both fertilized with wood ash and unfertilized. Svensk. bot. Tidskr. 45: 309-319. fa

A study on drained peat bog under 4 treatments, (1) unfertilized, (2) moderately fertilized with wood ash in 1918, (3) part of (2)

refertilized in 1949, and (4) heavily fertilized with wood ash in 1926. The N, P, K, and Ca contents of leaves of *Betula verrucosa* and *B. pubescens* were investigated. Birch leaves collected from the same area in two different years had, on the whole, a very similar composition. In (3), however, K and Ca contents of leaves were greatly increased after refertilization, but N and P showed no increase. The P and Ca contents in (1) and (2) were much the same; K content was slightly higher in (2) than in (1). In (4) P, Ca, and K were all significantly higher than in (1) and (2), 24 years after treatment. N content, however, was higher in (2), low in (1), and intermediate in (4). The results indicate that birch leaf composition can be a sensitive indicator of site properties, though it cannot be relied upon always to reflect the absolute amount of nutrients available per unit area.

TAMM, C. O. 556

1953 Mera om granens gulspetssjuka (More observations on the "yellow tip disease" of spruce). Svenska SkogsvFören Tidskr. 1953 (4). (Swedish w/English summary)

TAMM, C. O. 557

1954 a Some observations on the nutrient turnover in a bog community dominated by *Eriophorum vaginatum* L. Oikos 5: 189-194.

TAMM, C. O. 558

1954 b Om gödsling av skogsmark i Tyskland och Sverige (Fertilization of forest land in Germany and Sweden). Svenska SkogsvFören. Tidskr. 52: 263-286. (Swedish)

TAMM, C. O. 559

1954 c Svenska undersökningar över skogens näringtillständ (Swedish investigations of forest nutrient conditions). Växt-närings-Nytt 10: 14-18. (Swedish)

TAMM, C. O. 560

1954 d Om gödsling av skogsmark i Tyskland och Sverige (Fertilization of forest land in Germany and Sweden). Medd. SkogsforsknInst. Stockh. 34. 38 pp. (Swedish)

TAMM, C. O. 561

1955 a Studies on forest nutrition II. An experiment with application of radio-active phosphate to young spruce and birch, Medd. SkogsforsknInst. Stockh. 45 (6). 10 pp. (Swedish summary) L

An experiment with addition of P^{32} to a young spruce plantation was made in May 1954. Conclusions are drawn about the range of the spruce roots in this habitat, and about the amounts of radioactive isotopes suitable for ecological experiments with forest trees. The leaves of some birches growing within the experimental area contained a higher proportion of active phosphate than the young needles of spruces growing at the same distance from the source of activity, as measured one month after treatment.

Growing spruce needles contained a higher proportion of active phosphorus than older ones, but the comparatively high figures for the activity of the phosphorus in both one and two year old needles show that an intense exchange of phosphorus compounds must occur between these needles and other organs.

TAMM, C. O. 562

1955 b A study of forest nutrition by means of foliar analysis. Abstr. Int. bot. Congr. 8th Paris. 5 pp.

TAMM, C. O. 563

1956 a Studier över skogens näringsförhållanden III. Försök med tillförsel av växtnäringsämnen till ett skogsbestånd på mager sandmark (Studies on forest nutrition III. The effects of supply of plant nutrients to a forest stand on a poor site). Medd. SkogsforsknInst. Stockh 46 (3). 84 pp. (Swedish w/English summary) L

In the spring of 1951 two fertilizer experiments were laid out in a 30 year old pine stand (with some admixture of birch and spruce) at Mölna Experimental Field near Vaggaryd, central South Sweden. One of the experiments was a nitrogen fertilization, where ammonium nitrate was given in different dosages. The other experiment was a so-called minus experiment with both nitrogen and mineral salts.

The growth of the pines has been measured on increment cores collected in 1954. The nitrogen response followed the well-known Mitscherlich curve. The dominant pines increased their growth with up to about 65% of the control growth during the second

summer after treatment. Their nitrogen supply then appeared almost optimal to judge from the shape of the Mitscherlich curve. Weaker pines appeared to suffer more from nitrogen deficiency than the dominant ones.

The results from the minus experiment are not quite clear. Yet there is a considerable N effect here also. Direct and indirect positive effects of the mineral salts are not excluded, but the trace element addition appears to have had a certain deleterious effect.

The contents of N, P, K and Ca in the needles of pine and spruce and in birch leaves from the nitrogen experiment have been followed by annual samplings from before the treatment, and within the minus experiment. The changes in foliage nutrient concentrations are discussed in relation to growth. It is concluded that under the experimental conditions optimal diameter growth in pine is obtained where the N content of current and 1½ year old needles is about 2-2.5% of dry weight; for spruce the optimal N level does not lie below 2%, and not below 3.2% for birch leaves.

The interrelationships between growth and internal nutrient concentration are discussed both in relation to the Mölna experiment results and to data about "deficiency levels" of different nutrients, known from experiments in other places. Some remarks are made bearing on the use of foliar analysis as a diagnostic method in the study of forest nutrition.

TAMM, C. O. 564

1956 b Studier över skogens näringsförhållanden. IV. Effekten av kalium och fosfortillförsel till ett oväxtligt bestånd på dikad myr (Studies on forest nutrition. IV. The effects of supply of potassium and phosphorus to a poor stand on drained peat). Medd. SkgosforsknInst. Stockh. 46 (7). 27 pp. (Swedish w/English summary) A

In the study of forest growth on drained peat land, chlorosis has often been observed in Norway spruce growing on peat rich in lime. This chlorosis only affects needles older than the current ones, which have a normal dark green colour. The growth is also affected, and also Scots pine and birch (*Betula pubescens*) grow less well in most of the habitats studied than might be expected on well drained fen peat. Pine needles are often yellowish, and birch leaves yellowish or brownish along the margins, although these symptoms are less characteristic than those of the spruces.

Chemical analyses of needles and leaves with the described symptoms showed low contents of potassium and phosphorus, but high nitrogen and calcium contents. On the suggestion of Professor C. Malmström, who first observed the chlorosis, the present writer laid out a fertilizer experiment in the autumn of 1953 in an area in central Sweden, where the spruces suffered from severe chlorosis over a large area. The birch stand was also very poor, and the same was true of the pines growing in the area. The different plots were very similar with regard to vegetation and stand.

The stand grew up after a first draining in 1892-94, and a second and more thorough one in the Twenties and Thirties. Before draining much of the area was used for hay-making. At first the young stand seems to have grown well; now it appears almost checked.

The fertilizers used were superphosphate, orthophosphoric acid, basic slag, and so-called 50 per cent potassium sulphate from Alsace. Each dressing contained approximately 100 kg/ha of either phosphorus or potassium. The phosphoric acid was watered out, diluted with water, and the other fertilizers were spread out dry.

Already in the first summer after treatment a strong change in colour was observed on plots "K" and "KP". Here the spruces were no longer chlorotic, and also the pines and birches appeared more healthy. The addition of phosphate fertilizers (plots "PSuper", "PH_3PO_4" and "P Thomas") had no positive effect; indeed the deficiency symptoms were stronger than outside the fertilized area. In 1955 the growth increased notably in the spruces of plots "K" and "KP", the increase was somewhat larger in plot "KP" than in plot "K", but the difference is probably not statistically significant. The growth on the "P" plots was similar to that in the control plot.

The results so far reported show that the chlorosis of the spruces at Kyrkebymossen described here is caused by potassium deficiency. The same result was obtained by Malmström in an experiment at Salsta (personal communication). Needles from some other sites with similar chlorosis also contain very little potassium, and it seems clear that these habitats suffer from potassium deficiency. The differences between the symptoms described here and those reported by Heiberg & White (1951) and Björkman (1953) must be explained by differences in soil conditions, tree species, and tree ages.

The low potasssium concentration in foliage of spruce, pine and birch from unfertilized plots, or phosphorus fertilized plots, at Kyrkebymossen must be considered as within the deficiency range. The application of potassium sulphate has increased the potassium

level in all three species to quite normal values. In birch the phosphorus additions (particularly as superphosphate) have resulted in extremely high phosphorus concentrations in the leaves in the first summer after treatment. At the same time the potassium percentages decreased somewhat on the "P" plots, which is in good agreement with the observation that the visual symptoms worsened there.

Although it seems well possible to convert a very poor stand, suffering from potassium deficiency, into a healthy one by application of potassium salts, such treatment cannot be recommended for practical purposes on a large scale, before we know how long the effect will last. It is also very possible that an addition of potassium will result in a phosphorus deficiency after a shorter or longer period of good growth.

TAMM, O. 565

1942 Några synpunkter på den svenska skogens fosfatfråga (Some points of view on the phosphate problem in Swedish forests). Svensk bot. Tidskr. 36: 383-389. (Swedish) fa

A strong protest is made against the assessment of the phosphate status of Swedish forest soils by analytical methods primarily designed for soils under field crops. Any chemical methods for determining the nutrient requirements in forest soils must differ widely from these. The phosphate requirement per ha. per year are much lower in the important forest trees than in field crops. Pine, spruce, and birch, in particular, often do well on soils that are extremely poor judged by agricultural standards, and are most probably able to make better use of "bound" soil nutrients than are agricultural plants. Particular stress is laid on the occurrence of apatite in moraine deposits, gravels, sands, etc., and on the probability that this mineral may furnish phosphate directly to forest trees, as it is comparatively soluble under acid conditions. Trees have a long life, and the amount of nutrients available at a particular time does not correspond to what may become so throughout their lifetime. Harvesting timber does not remove any appreciable quantity of phosphate, as the stems contain only negligible amounts and the slash is left on the site. Losses by leaching are also slight owing to good retention of phosphate ions by the soil. The fertilizing of forest soils, if economically practicable, would imply the use of relatively insoluble fertilizers that would release their nutrients gradually over a long period.

TASMANIAN FORESTRY COMMISSION 566

1952 Use of fertilizers in plantations of *Pinus radiata*. Rep For. Dep. Tasm. 1951-52: 12. fa

Plots in the Beaconsfield Plantation were treated in August 1949 with commercial superphosphate at a rate of 8 cwt./acre. As early as March 1950 the effect of the treatment was seen in improved color of young needles. In November 1950, the new season's needles on the treated plots were twice as long as comparable ones on the untreated plots; trees that had carried fused needles produced normal needles and in some cases previously fused needles had separated. For the 1949-50 growing season there was no significant difference in diameter growth between plots, but for the 1950-51 season the treated plots showed significantly higher increases in diameter, and this difference was still greater in the following season.

TAZAKI, T. 567

1950 The fate of seedlings of *Pinus thumbergii* in relation to the chloride content of the soil. Bot. Mag., Tokyo. 63: 12-17. fa

In laboratory experiments, seeds were sown and seedlings grown in containers, in sand moistened with different strengths of NaCl solution or of diluted sea water. The number of seeds to germinate decreased, and germination was retarded, when the Cl exceeded 20 mg./100 g. dry sand (0.20-0.50% of the sand moisture) and germination almost ceased when it exceeded 60 mg. (0.55-1.50%). In tests on seedlings, survival about 1 month after germination was similar to that of controls at Cl concentrations below 0.3% of the sand moisture and was considerably reduced for concentrations above 1%. Survival was a little higher when the sand had been moistened with sea water. Salt concentrations in sand dunes are generally low enough to allow seedling growth.

TERENT'EVA, N. L., M. S. AKIMENKO, AND K. A. KUCHERENKO 568

1954 (Experimental application of fertilizers when raising seedlings of deciduous trees). Les. Khoz. Lesoeksp. 12: 26-28. (Russian)

THEMLITZ, R. 569

1951 Bewertung von Hütenschlacken für forstliche Düngung (Appraisal of foundry slag for forest fertilizing (liming)). Forstarchiv 22: 143-146. fa

Reports briefly on the author's small scale experiments with a number of German foundry slags containing 39-54% CaO and 2.5-6% MgO. For adjusting soil pH, most of these were ca. half as effective as pure $CaCO_3$, but their base content and particle size were useless as indexes to their value for this purpose, and test on two different soils showed that one and the same slag could have very different effects on different soils. In a further experiment, screefed plots on a biologically active soil were covered in June 1950 with raw spruce humus (1) untreated, or with lime mixed in, before spreading, as (2) $CaCO_3$ or (3) one of 3 different slags. After 8 months (1) showed no earthworm activity and no noticeable change from its initial state; (2) had been almost completely incorporated by earthworms into the mineral soil, and (3) varied as regards earthworm activity and degree of incorporation according to the slag used, but none of the slags approached $CaCO_3$ in effectiveness. Tests of the humus at the end of the period revealed that although both $CaCO_3$ and the slags had produced very favorable changes in pH, exchangeable CaO and citric-acid-soluble P_2O_5, only $CaCO_3$ had caused any significant increase in N content. It remains to be shown by further investigation whether the apparent inhibition of biological activity by the slags is related to their sulphide content.

THEMLITZ, R. 570

1953 a Beitrag zur Phosphorsäurefestlegung durch verschiedene gealterte Eisenoxydhydrate und Phosphorsäureaufnahme durch Kiefern im Gegenwart solcher Hydrate bei verschiedener Reaktion (Contribution to the fixation of phosphoric acid by several reduced ferrous oxide hydrates and the absorption of phosphoric acid by pines in the presence of such hydrates at different reactions). Phosphorsäure 13: 220-231.

THEMLITZ, R. 571

1953 b Bewertung von Bodenanalysen zur Beurteilung forstlich genutzter Standorte (The value of soil analysis in the evaluation of forest sites). Z. PflErnähr. Düng. 61: 65-71.

A review of German work. The generic nature of the soil is a better characteristic than the soil reaction and soil nutrients. In the fertilizing and liming of young plants, especially on mineral soils, analysis is often desirable.

THEMLITZ, R. 572

1954 a Kan det löna sig att använda handelsgödsel på skogsmark (Is it profitable to apply commercial fertilizer to forest areas)? Växt-närings-Nytt 10: 19-24. (Swedish) a

Nursey manuring in Germany is based mainly on dung or compost fortified with lime and NPK if necessary. Nurseries should be tested for fertilizer response before a manuring program is used. Fertilizing of forest stands is increasing, particularly with N, after appropriate adjustment of soil reaction by liming. N fertilizing is most likely to pay with exacting trees such as poplar.

THEMLITZ, R. 573

1954 b Die Anwendung von Kalkstickstoff zur Rohhumusumwandlung und Ertragssteigerung im Walde (The application of calcium cyanamide for the transformation of raw humus and production increase in the forest). Z. Pfl-Ernähr. Düng. 64: 54-66. A

For the purpose of raw humus transformation and production increase a 60-year-old spruce stand on loess containing red sandstone was fertilized with calcium cyanamide, lime, as well as with both fertilizers together. The combined fertilization proved to be most favorable with regards to the formation of nitrogen-abundant humus substances, improvement of the absorption capacity and the mobilization of P_2O_5.

Needle analyses showed that the nutrient uptake was promoted by the three fertilizers. The transformation of raw humus is due to the reaction of the ammonia, formed during the breakdown of the calcium cyanamide. Separate examination confirmed the results of Wittich's experiments according to which ammonia is partly fixed in a way that it can be easily separated and is further, quite probably, partly fixed heterocyclicily to a considerable degree.

The firmly fixed nitrogen fraction increased with the duration of the action of the ammonia.

THEMLITZ, R. 574

1955 a Beitrag zur Wirkung von Hüttenkalken auf die Rohhumusumwandlung und das Wachstum von Kiefernsämlingen (Contribution on the effect of foundry lime on the raw humus conversion and growth of pine seedlings). S.B. dtsch. Akad. Wiss. IV: 3. A

Basic slag which may be marketed as lime fertilizer has proven to be at least equally effective in experiments concerned with the transformation of raw humus. The higher the concentration of bases of the quicklime the better was its effect regarding the improvement of the reaction and the absorption capacity. This also applied to the availability of easily soluble calcium and magnesium. Lime fertilization experiments with pine seedlings on a loam soil demonstrated that basic slag is at least as effective as calcium carbonate, and was even superior on humic heathland soil, extremely poor in nutrients. On this soil basic slag contributed to an improved manganese supply of the pine, whereas according to experience calcium carbonate and mixed lime had depressed the manganese content.

THEMLITZ, R. 575

1955 b Zur Frage der Ausnutzung des von Rohhumus aus Ammoniak in fester Bindung aufgenommenen Stickstoffs und der Stickstoffaufnahme aus schwefelsaurem Ammoniak und Kalkammonsalpeter im Gegenwart von Rohhumus durch Nadelholzsämlinge (The utilization of ammonia nitrogen from stable raw humus compounds and the uptake of nitrogen from ammonium sulphate and calcium ammonium nitrate by coniferous seedlings in the presence of raw humus). Z. PflErnähr. Düng. 70: 207-220. A

It is known that when raw humus is treated with ammonia, a part of the applied nitrogen is fixed. Spruce seedlings grown in Neubauer dishes were not able to satisfy their N-requirement from the fraction of fixed nitrogen in the ammonia-raw humus. Nitrogen fixation by spruce raw humus which is of great importance for the N-uptake of spruce and of pine seedlings could not be observed after an application of ammonium sulphate or of nitrate of lime and ammonia fertilizers. Although N-utilization was most remarkably high, the raw humus remained unproductive if no provisions were made for a sufficient supply of other nutrients at the same time.

THEMLITZ, R. 576

1956 Der Einfluss einer Phosphatdüngung auf den Nährstoffgehalt der Nadeln bzw. Blätter verschiedener Holzpflanzen auf gleichen Standorten und die Eignung des Thomasphosphats zur Manganversorgung von Nadelholzsämlingen (The

fertilization influence of phosphorus with regard to the content of nutrients of needles and/or leaves of different forest trees growing on the same site and the applicability of Thomas slag in respect to the supply of manganese to coniferous seedlings). Phosphorsäure 16: 92-104. A

In a mixed plantation of spruce, poplar and alder on a peaty diluvial soil, with the ground water table near the surface, a fertilization with lime marl gave disappointing results; the effect of a phosphorus application, however, was more favorable.

The P_2O_5 absorption from both Rhenania and Algier phosphate was increased more in poplar than in spruce and alder. Alder evidently utilized the soil phosphorus better than did the spruce or poplar.

The experience was confirmed that, in the case of spruce and pine seedlings, rock phosphate is no less effective than Rhenania or Thomas phosphate. Thomas phosphate (basic phosphate slag) favored the manganese supply of the seedlings.

For the evaluation of the prospective results of a phosphorus fertilization of seedlings and plants, the limiting values for citric acid soluble phosphorus as established by Süchting are suitable.

As far as the chances of success of a stand fertilization is concerned it is recommended to use, more than was the case until now, the nutrient content of the assimilation organs as a governing factor, because where the soil is in good physical condition, older trees are able, with their deepgoing root system, to compensate for the absolute nutrient deficiency.

According to fertilization experiments with labeled Rhenania phosphate pine seedlings absorbed the fertilizer phosphorus in preference to the soil phosphorus. The uptake of fertilizer phosphorus corresponds to the longitudinal growth and increases rapidly with the formation of the terminal buds. The accumulation of phosphorus in the terminal buds could be demonstrated radiophotometrically.

THIELMAN, K. 577

1951 Waldbodenmelioration. Erkentnisse und Erfahrungen aus der Wiederaufforstung geringer Kiefernstandorte in der Oberpfalz (Forest soil improvement. Diagnosis and experiences from the reforestation of inferior pine sites in the Upper Palatinate). Mitt. StForstvern. Bayern. 26: 67-124. fa

A summary report based on 20 years' experience in the restoration of soils carrying stunted pines, leading to recommendations. A series of soil-profile diagrams shows where heavy disking, ploughing, high-ridging and subsoiling are needed, and types of implements with their working widths and depths are illustrated. Tractors of 60-80 h.p. are recommended. $CaCO_3$, marl, and CaO are applied according to the consistence of the soil, the dosage being calculated on H. Walter's table which requires the following amounts of CaO in kg./ha. to raise the pH by one,—sands 500, loams 1500, heavy loams 3000, soils with 15% humus 4000-8000. Normally 2000-3000 kg. CaO/ha. are applied. A detailed table shows the preliminary costs (soil amelioration) at ca. DM. 200/ha., which is raised to nearly DM. 800 with planting and sowing completed. This latter includes the direct sowing of 10 kg. of lupine and 20 of birch, the planting of 500 larch, 1000 each of alder, willow, and spruce, 2000 each of oak and lime, 5000 *Pinus strobus* and 10,000 *P. sylvestris*. Growth on areas high-ridged with a locally developed "Bifang" plough is shown in a table to be three times as great in 19 years as adjacent untreated sites can show in 28. Photographs illustrate root development on this ridge.

THURMANN-MOE, P. 578

1946 Svenske og norske forsøk med gjødsling av skogsmyr (Swedish and Norwegian experiments on fertilization of forest bogs). Tidsskr. Skogbruk 54: 160-172. (Norwegian)

THURMANN-MOE, P. 579

1954 Aktuelle problemer i skogsgrøftingen (Present problems in forest drainage). Tidsskr. Skogbruk 62: 53-62. (Norwegian) fa

Gives a graph showing the relationship between low timber prices and increased drainage operations in Norway from 1910 to 1940, and discusses the improvements and increased use of blasting for making drains since the war, the area suitable for drainage, and already drained, and some examples of tree growth on the drained areas and the effect of thinning and the use of fertilizers.

TILLOTSON, C. R. 580

1917 Nursery practice on the national forests. Bull. U.S. Dep. Agric. 479. 86 pp.

Tjulin, A. F., S. V. Kushnirenko and K. G. Scerbina 581
1953 (The mineral nutrition of oak and of associated vegetation on dark grey forest soils). Pedology, Leningr. 3: 19-28. (Russian) fa

Trials have been in progress in several oak woods in the drier parts of Russia to determine the possibility of increasing the seed yield and frequency of seed years by mineral fertilizers, including trace elements. In one of these woods on a rich soil in the Tellerman experimental forest, Voronezh, periodical analysis of soil samples through the growing seasons of 1951 and 1952 revealed that there was a marked decline of C, N, and P in June and July in the soil horizon 3-15 cm. deep,—the zone of maximum rooting density. This decline occurred on both treated plots and controls, but was temporary, the contents of these elements being almost or quite restored to their original values by October. To demonstrate that the decline was due to absorption by roots, litter was removed from a plot 2 m. square, the soil was removed to 15 cm. depth and transferred, after all visible roots had been picked out, to a similar plot excavated to the same depth and provided with board sides to exclude roots. The root-free plot (kept weeded) did not show the decline in the 3 elements. The mechanism of restoration in the second half of the growing season is a matter for further research. Some analyses of fine roots suggest that not all of the quantity of N and P absorbed is transported to the stem and crown. Further, it is estimated that the amount of N disappearing from the main rooting zone in June-July may be 15-10 times that returning to the soil via the litter. The authors confine themselves to the first hypothesis of return through the roots by exosmosis and in part by decomposition of roots; selected data are tabulated.

Results of the fertilizer treatments (not detailed) on growth and seed production are said to be very promising. The applications per tree were 3 kg. superphosphate, 0.5 kg. each of NH_4NO_3 and KCl, and 0.5 g. each of B, Zn, and Cn (all the trace elements being applied as solutions).

Tjulin, A. F. and K. G. Scerbina 582
1954 (The biological cycle of N and P between vegetation and soil in the deciduous forests on the southern portion of the forest-steppe during the growing season). Dokl. obsch. Sobr. Ak. Nauk SSSR 97: 125-128. (Russian).

TOUMEY, J. W. AND C. F. KORSTIAN 583

1942 Seeding and planting in the practice of forestry. 3rd ed., xxii + 520 pp., John Wiley, New York

TRESCHOW, C. 584

1934 Gødningsforsøk i Ask (Forest fertilization with ash). Dansk Skovforen. Tidsskr. 19: 233-252. (Danish) Ba

A test of the effect of various fertilizers on the height growth of seedling ash was carried on from 1925 to 1933. This summary shows the effect of litter alone and of litter plus fertilizer upon height growth. Apparently the poorer the soil, the greater the beneficial effect of litter, but the less the increased advantage of additional fertilizer. On a very poor site the fertilizer had no additional beneficial effect. It seems therefore far more important to place ash seedlings under suitable natural growth conditions than to practice artificial fertilizing. 10-30% greater height growth can be obtained by the addition of litter and fertilizer, but the right condition of shade alone can make an increase of 30-62%.

TRIBUNSKAYA, A. Y. 585

1954 (The removal of nitrogen and phosphorus by pine seedlings on grey forest soils). C. R. Acad. Sci. U.R.S.S. 97: 929-930. (Russian)

TRIMBLE, JR., G. R. AND S. WEITZMAN 586

1956 Chaff seeding—One answer to soil washing on logging roads. W. Va. Conserv. (Feb.) 2 pp.

TRINIDAD-TOBOGO FOREST DEPARTMENT 587

1954 Response to chlorotic *Pinus caribaea* to fertilizer. Rep. For. Dep. Trin. Tob. 16.

TSCHERMAK, L. 588

1950 Waldbau auf pflanzengeographisch-ökologischer Grundlage (Silviculture on the basis of plant geography and ecology). xiv + 722 pp. Springer, Wien.

TSUTSUMI, T., et *al.* 589

1954 (The effect of fertilization on the growth of 6-year old, natural regenerated pine (*Pinus densiflora*) stand Prelim. Report). Res. Rep. Coll. Akamatsu. 1954: 31-37. (Japanese w/English summary) L

This study was undertaken to determine the effects of fertilization on the growth of young pine stand on the poor soil. The natural regenerated 6 year old pine stand in Akanuma (Saitama Pref, Japan) was chosen for the study, and each of the following treatments was applied to 8 plots set up in 1951: A. soil improving trees planted plus fertilizer; B. soil improving trees without fertilizer; C. fertilizer alone applied; D. untreated (control). The effect of fertilization was evident in 1954 (fourth growing season after treatments), but the effect of the soil improving trees was not yet recognized; and the difference in height of pine trees between A, C and B, D was statistically significant.

Tulstrup, W. P. 590

1951 Et gødningsforsøg i Egelund planteskole (An experiment with fertilizers at the Egelund nursery). Dansk. Skovforen. Tidsskr. 36: 105-114. (Danish) fa

Plots were manured with combinations of N(350 kg. $Ca(NO_3)_2$/ha.), P (150 kg. 18% superphosphate/ha.), K (150 kg. 40% K fertilizer/ha.), or NH_4 (350 kg. $(NH_4)_2SO_4$/ha.), or with stable manure or were left untreated, before planting with 2-0 Norway and Sitka spruce and 1-0 Scots pine, silver fir, larch, beech, and alder. Height measurements after 18 months are shown in graphs. Beech treated with N showed increased height growth, but with NH_4 or 2K (300 kg./ha.) height growth was rather below average. Alder on poor soil showed much increased height growth when treated with N + P, or with stable manure; results on richer soils were less conclusive; K reduced height growth. 2P + K + N and 2N + K + P stimulated height growth of Sitka spruce, while 2K reduced it. Scots pine showed an increase in height growth when treated with K, or N + P, but a reduction when treated with 2K. Silver fir showed reduced height growth when treated with 2K, and no definite increase for any treatment. Norway spruce showed an increase in height growth when treated with K, but a decrease when treated with 2K or 2N. The larch was too much damaged by insects for conclusions to be drawn. Some figures for cost of the different fertilizers are given.

Uchida, T, and K. Tsuda 591

1954 a (Studies on phosphate manure. I. Amounts of calcium influencing increase of available phosphate fertilizer). Spec. Rep. Hokkaido For. Exp. Sta. 2: 7-12. (Japanese)

Uchida, T, and K. Tsuda 592

1954 b (Manure experiment of *Larix*. 2. Influence of soil texture on growth of young trees). J. Jap. For. Soc. 36: 193-195. (Japanese w/English summary) Ba

Seedlings of *L. kaempferi* were planted in loamy sand, light clay, and volcanic ash, all fertilized well, and their growth was compared. Height and green weight of seedlings lined up as: loamy sand > volcanic ash > light clay. N, P, and K contents of seedlings were in the following rank order: volcanic ash > light clay > loamy sand.

Uchida, T., Y. Matsumoto and K. Tsuda 593

1953 (Studies on the effect of three constituents in the fertilizer on the growth of young trees (*Larix kaempferi*, Serg.)). Sym. Ann. Staff Conf. Sapparo Branch Gov't. For Expt. Sta. 1952-53. (Japanese) faA

Height growth increased slightly with increasing N and considerably with increasing P. Maximum green weight was obtained with the addition of 8 kg. N, 14 kg. P, and 10 kg. K per ton (0.245 acre) to the soil, and root weight increased with increasing amounts of P.

Ursic, S. J. 594

1956 Late winter prelifting fertilization of loblolly seedbeds. Tree Plant. Notes 26(10): 11-13. W

The effects of prelifting winter fertilization (160 lbs. N and 200 lbs. K_2O per acre) of nursery seedbeds on survival and early growth of normal loblolly seedlings planted on adverse sites in north Mississippi were studied.

As recorded in mid-October 1955, first-year survival for all seedlings averaged 75 percent. The survival analysis showed:

1. There was no apparent difference in survival due to site.

2. There was no apparent advantage in using large as opposed to small planting stock.

3. Late seedbed fertilization in the nursery as applied in this study had a detrimental effect on seedling survival. Survival of fertilized trees averaged 69 percent while survival of unfertilized seedlings averaged 81 percent. Statistically, the differences are highly significant.

On the basis of this limited test, prelifting winter fertilization of normal loblolly seedlings to improve field performance cannot be recommended. The one-level fertilizer treatment decreased survival, and did not improve vigor or height growth. This does not, however, discount the value of prelifting fertilization of unthrifty or chlorotic stock, as only normal seedlings were used in the test.

VAARTAJA, O. 595

1954 a Mineral deficiencies in a forest nursery. Prog. Rep. Div. For. Biology, Can. 10(2). fa

Application of N in the form of $(NH_4)_2 SO_4$ to seed beds before sowing had little effect on growth of conifer seedlings in N-deficient soil, and no effect on their chlorosis. Application of NH_4NO_3 in liquid form (70-140 lbs. N/acre) in August to seed beds of 3-year-old spruce gave promising preliminary results; the yellow color of the foliage rapidly changed to deep green and the buds grew larger.

VAARTAJA, O. 596

1954 b Correction of chlorosis in (white) spruce seedbeds. Prog. Rep. Div. For. Biology, Can. 10(5). fa

Further experiments confirm the earlier finding of the superiority of applications of N-fertilizer in liquid form to seedbeds after emergence, rather than before sowing. Repeated treatment is necessary in dense seedling stands. Shading the beds with screens decreased chlorosis, though to a less degree than fertilizer treatment. This effect of shade is not yet understood.

VALIKOVA-KANDAUROVA, V. E. 597

1949 (Growth and development of some species with mineral fertilizers). Dokl. obsch. Sobr. Ak. Nauk S.S.S.R. 68: 945-948. (Russian)

VAN GOOR, C. P. 598

1953 a The influence of nitrogen on the growth of Japanese larch (*Larix leptolepis*). Plant and Soil 5: 29-35. fa

Pot-culture tests were used to determine the influence of N and P on the growth of *L. leptolepis*. Average dry weight of shoots was used as a standard for determining growth, and leaf analyses were

made to demonstrate the absorption ratio of the nutrients. The results indicate an N/P antagonism in Japanese larch. N decreases the intake of P, and vica versa. The growth reaction depends, however, on the N and P content of the soil. Growth is optimal over a narrow N/P ratio range, and decreases rapidly on both sides of this optimum. The poorer the soil in P, the more rapidly growth decreases as the supply of N is increased. In soil rich in P, absorption of this nutrient will be decreased by additional N but, because of the availability of excess P, the N/P ratio in needles will not increase much above the optimum. In such cases added N may increase growth. P does not have a harmful effect on growth, except where only a little N is present. The ecological character of larch as a pioneer species is discussed in relation to its low need for N and the N/P antagonism.

VAN GOOR, C. P. 599

1953 b Groeiremmingen bij de Japanse lariks (*Larix leptolepis*) ten gevolge van kalkbemestingen (Growth checking of Japanese larch (*L. leptolepis*) as a result of liming). Ned. BoschbTijdschr. 25: 57-68. (Dutch w/English summary)

The results of some liming experiments in Japanese larch (*Larix leptolepis*) point to a tendency of decreasing growth by increasing quantity of lime. As liming in forestry can be considered as an indirect nitrogen fertilization, this phenomenon corresponds with the preliminary results of the site research in the permanent sample plots of the Japanese larch. In these sample plots the site quality of the larch seems to decrease with increasing nitrogen content of soil and leaves. This relation between growth of larch and the nitrogen and phosphate nutrition is tested in a pot culture experiment. The nitrogen and phosphate are varied in three different kinds of soil. The total quantity of NH_4NO_3 and H_3PO_4 added to each pot with 4000 grams of soil and 13 plants is mentioned.

The reaction of the larch to nitrogen seems to depend on the N and P content of the soil. In a soil poor in N and P the growth is increased by N, when given in small quantities and in combination with P. Greater quantities of N decrease the growth. The development of the seedlings decreases with N when the soil is poor in P and rich in N. The reaction of larch to N in a soil rich in N and P is weak, but positive. P always increases the growth, except when there is no or only very little N present.

The results of the liming experiments correspond with the re-

action of the larch in the pot culture tests, as the common forest soil is poor in P and normal rich in N.

Though these sample plots do not fulfil the statistical requirements, they can give in combination with pot culture tests, leaf and soil analysis and so on, valuable insight into questions, where any definite answer is lacking.

VAN GOOR, C. P. 600

1954 Bemesting in de bosbouw (Forest fertilizing). Tijdschr. ned. Heidemaatsch. 65: 235-240. (Dutch w/English summary)

VAN GOOR, C. P. 601

1955 De fosfaatbehoefte van bomen en de fosfaatbemesting in de bosbouw (The phosphate requirements of trees and phosphate fertilizing in the forest). Het Thomasmeel 11: 251-257. (Dutch) A

Besides nitrogen, phosphate is an important nutrient for trees. However, there is some difference in the use of phosphate by different trees. In this respect *Pinus* species have lower demands than larch, Douglas fir, spruce or hardwood.

As trees can use little soluble phosphates the amount of total phosphate in the soil of the main rooting zone has proved to be a good indication for the level of that nutrient. With an amount of 20 mg. total phosphate per 100 grams of soil the minimum is reached for the more demanding species. For *Pinus* this seems to be the optimum level. At an amount of 50 to 70 mg. total phosphate the optimum phosphate demand of the more exacting species is fully covered.

For phosphate fertilization on the basis of soil analysis the following scheme has been developed:

Total phosphate in soil	Fertilization of P_2O_5 in kg./ha.	
	Pinus spp.=	Larch, Douglas, spruce and other species
0-10 mg. P_2O_5/100 g. soil	0-125	>500
10-20 "	-	250-500
20-30 "	-	125-250
30-40 "	-	0-125
>40 "	-	0

1956 a Standort und Düngung von japanischer Lärche (*Larix leptolepis*) in den Niederlanden (Location and fertilization of Japanese Larch (*Larix leptolepis*) in the Netherlands). Phosphorsäure 16 : 81-91. A

By planting fast-growing timber species, selection of species on the basis of soil characteristics and by fertilization, a considerably increased production of timber can be attained in the Netherlands without changing the forest area. Research of the growth relationships of the most important timber species shows that there is a scientific basis for the application of the necessary measures.

Japanese larch is one of the most economically important timber species. It has high demands on the water regimen and the P-condition of the soil, and it requires a low pH value.

A large part of the larch stands is on soils with a total P-content of 15-25 mg./100 grams of soil which represents the minimum for this species. From a P-fertilization, with the amount depending on the results of a soil analysis, an increased production of about 30% can be expected. This fertilization has been started on a large scale.

1956 b Kaligebrek als oorzaak van gelepuntziekte van groveden (*Pinus sylvestris*) en Corsicaanse den (*Pinus nigra* var. *Corsicana*) (Potassium deficiency as a cause of yellow tip disease in Scots pine and Corsican pine). Korte meded. RijksboschProefst. 25: (In print). (Dutch) A

Yellow tip disease of *Pinus* species is seen frequently in young plantations on poor heath podzols developed in cover sands, fluvioglacial sands and inland sand dunes. The cause of this disease mostly is a deficiency of potassium. The critical level of potassium in the current needles—sampled in autumn at the top of the trees—amounts to ± 0.35% of the dry matter for Scots and ± 0.30% for Corsican pine. Under certain conditions where there is a deficiency of other nutrients, yellow tip disease can occur at higher potassium contents. This is the case on inland dune soils, rich in potassium and very poor in other nutrients. Manganese does not show any important influence. Increase of the amount of nutrients except potassium will already result in an improvement of the stand on these soils. There is a good correlation between the length of current shoots and the potassium content of needles.

To be able to give a prognosis, it is necessary to know the relation between the nutrient content of the soils and that of the needles. It seems to be profitable to use strong extractants for analyzing the soil. It is of no use to extract the soil with 0.1 N HCl as the variation of the values of potassium content obtained by that is very small. The potassium content, obtained by extraction of soil with 5% HCl is more reliable and correlated well with the potassium content of the green needles. The critical level of the potassium content of soils is at about 0.006 to 0.012% K_2O, soluble in 5% HCl. This is only the case on the poorest soils. The soil type therefore is a useful criterium for the possible occurrence of yellow tip in *Pinus* spp. The therapy of yellow tip disease consists of fertilization with potassium fertilizers. Potassium sulphate is preferable to potassium chloride. In serious cases a combination with basic slag and magnesium sulphate may be worthwhile.

VANSELOW, A. P. 604

1945 The minor element content of normal manganese-deficient, and manganese-treated English walnut trees. Proc. Amer. Soc. hort. Sci. 46: 15-20. fa

Spectrographic analyses have been made of samples of walnut leaves from untreated and treated manganese-deficient trees, and from normal trees in two areas. The results for 15 of the minor elements show that manganese deficiency (a) does not seem to cause any material disturbance in the amount of other minor elements found in the leaf samples; (b) can be corrected if manganese sulphate is applied by spraying the tree during early summer or by injection of the dry salt into holes in the trunk or limbs. In general, the minor-element content of the walnut leaf does not differ greatly from that of the normal citrus leaf; barium is somewhat lower, and molybdenum and nickel are somewhat higher in the walnut leaf.

VATER, H. 605

1910 Tharandter Forstdüngungsversuche (Forest fertilization research at Tharandt) Tharandt. forstl. Jb. 61: 111-135.

VATER, H. AND H. SACHE 606

1927 Forstliche Anbauversuche, insbesondere Düngungsversuche (Experimental cultivation in the forest, particularly fertilizing trials). Arb. dtsch. LandwGes. 186 pp. Ba

These 23 experiments, mostly in Saxony, were undertaken with various methods of interplanting, litter removal, and soil treatment. Practically all fertilizers stimulated tree growth sooner or later, although to a varied extent, and in most cases the gain was not equal to the cost. Fish guano and potash were harmful to planted trees at first, but later stimulated those surviving. As they did no harm on seeded areas, the injury was probably through lesions in the roots of the trees. In some instances the foliage was a much darker green for a year or so following fertilization. Immediately following application of fertilizers there was a sudden invasion of plants typical of better sites such as *Senecio*, *Epilobium*, *Rumex*, *Hieracium*, and *Rubus*. These disappeared after a time. Experiments with various mixtures of red oak and Scotch pine, alder, and spruce were inconclusive because of injury by game and by frost, or because of poor soil. In pitch pine–Scotch pine mixtures, pitch pine grew faster at first, but fell behind after about 15 years. Removal of litter helped growth of pine on good soils with little vegetative cover. In several instances fencing against rabbits, deer, and other game had a greater influence than fertilizers in promoting growth.

VENEMA, K. C. W. 607

1953 Effects of potassium deficiency in conifers. Potash Rev. 22 (1). 3 pp.

VIRO, P. J. 608

1950 Fertilization trials on forest soils. Commun. Inst. for. Finl. 37: 1-23. (English and Finnish) A

This paper reports three exploratory fertilization trials. The soil was poor in nutrients and very coarse in texture. The fertilizers tried were: lime alone, total fertilization (Ca, P, K, N), and bog peat + lime.

The results show that decidedly the best effect was obtained when the water conditions of the soil were improved (peat + lime). Total fertilization also had a favourable effect whereas the effect of lime was only slightly positive.

The effect of fertilization lasted 8 years for lime, 10 years for total fertilization, and 14 years for bog peat.

VIRO, P. J. 609

1951 Nutrient status and fertility of forest soil I. Pine stands. Commun. Inst. for. Finl. 39 (4). 54 pp. (English w/Finnish summary)

VOIGT, G. K. 610

1949 Effect of fertilizer treatments on anatomical and physiological characteristics of nursery stock. M.S. Thesis. Univ. Wis. Library, Madison.

VOIGT, G. K. 611

1951 The effect of soil fertility on the physio-chemical properties of cell sap in forest tree seedlings. Ph.D. Thesis, Univ. Wis. Library, Madison.

VOIGT, G. K. 612

1953 The effects of fungicides, insecticides, herbicides, and fertilizer salts on the respiration of root tips of tree seedlings. Proc. Soil Sci Soc. Amer. 17: 150-152. BaA

The effects of various eradicants and fertilizers used in nursery practice on the O_2 uptake of excised root tips of seedlings of jack pine, red pine, white pine, and black locust seedlings was investigated using manometric techniques. The compounds studied included calomel, spergon, thiosan, chlordane, Stoddard oil, and common fertilizer salts applied at ordinary rates. In the 1st phase of the study the root tips were placed directly into solutions or suspensions of various compounds and their rate of O_2 uptake determined. The second phase was concerned with the respiration of root tips of seedlings grown in cultures treated with the chemicals. The measurements show that some of the compounds applied to nursery soils are inhibitory to the metabolism of roots of young seedlings. The results also indicate that manometric methods of analysis provide a useful tool for the evaluation of the effect of various chemical compounds used in current nursery practice.

VOIGT, G. K. 613

1954 The effect of fungicides, herbicides, and insecticides on the uptake of phosphorus by *Pinus radiata* as determined by the use of P^{32}. J. Amer. Soc. Agron. 46: 511-513. A

The effect of various fungicides, herbicides, and insecticides, on the accumulation of phosphorus by seedlings and excised root tissues of *Pinus radiata* was investigated using P^{32}. The results of greenhouse trials indicated that some of the eradicating agents inhibited the absorption of phosphorus and arrested the development of seedlings. This was especially true of aluminum sulfate, thiosan, and benzene hexachloride. Allyl alcohol and formaldehyde caused

increased absorption of applied phosphorus and stimulated the growth of the seedlings. Determinations of the oxygen uptake and phosphorus content of excised root tips and mycorrhizal short roots showed that reduction of phosphorus accumulation as indicated by the relative content of p^{32} and the content of total phosphorus in the tissue was accompanied by a decrease in the rate of oxygen consumption. This response occurred within a relatively short time after the tissues had been exposed to the biocides and was especially marked in the case of thiosan and benzene hexachloride. The results of the study point out the importance of obtaining uniform distribution of biocides in the soil as well as using the proper rate of application.

VOIGT, G. K. 614

1955 The effect of applied fungicides, herbicides, and insecticides on the content of nutrient elements in tissue of coniferous seedlings. Proc. Soil Sci. Soc. Amer. 19: 237-239. A

The effect of different eradicating agents used in nursery practice on the contents of nitrogen, phosphorus, potassium, calcium, and magnesium in needle tissue of coniferous tree seedlings was investigated. Jack pine (*P. banksiana*) and Monterey pine (*P. radiata*) were raised in nursery seed beds and greenhouse pot cultures on soils treated with biocides used singly and in combinations at different rates of application. The biocides investigated included aluminum sulfate, calomel, formaldehyde, thiosan, allyl alcohol, Stoddard oil, benzene hexachloride, and chlordane.

The responses of the seedlings to these compounds ranged from a stimulation of growth and an increase in the content of nutrients to a severe depression of the rate of growth accompanied by a reduction in the content of nutrients. The results of the study indicate that tissue analysis may serve as a useful tool in determining the effect of eradicating agents on the availability of nutrient elements to tree seedlings.

VOIGT, G. K., W. H. BRENNER, AND S. A. WILDE 615

1949 Liquid ammonia treatments of composted fertilizers. Proc. Soil Sci. Soc. Amer. 14: 281-283. BaA

The high C/N ratio and consumption of available N by cellulose decomposing microorganisms is a common cause of the "degenera-

tion," of composted fertilizers. The present study aimed to correct this shortcoming by using treatments of peat composts with liquid ammonia under pressure. Trials were carried on in specially constructed experimental concrete pits. Ammonia was delivered to compost samples by means of a steel pipe perforated with 1/32 inch openings arranged in a spiral, and connected to the metering device on the ammonia container by means of a rubber hose. The pipe was plunged into the compost and ammonia allowed to flow for various lengths of time. With a pressure of 10 lbs./sq. inch the radius of dispersion was about 12 inches. Under the conditions of this study the optimum rate of liquid ammonia application was 2-3 lbs. of elemental N/cu. yard. The growth effects of ammonia treated compost were studied in sand cultures and on experimental indicators. Increases in production of dry matter due to ammonia treatments ranged between 100 and 300%. In some instances application of ammonia treated compost produced seedlings of unusually vigorous appearance and, in the case of buckwheat, brought the plants to the flowering stage more rapidly.

Voinow, P. A. 616

1935 (The influence of sodium chloride, sodium carbonate, and sodium sulfate on seedlings of trees). Trans. Omsk. Inst. Agric. 1: 361-374. (Russian)

Vouk, V. 617

1953 (Auxins in forestry). Sumarski List 77: 1-11 (Croat.w/ English summary) fa

A criticism of Afanasijev's recent work, his inconsistent and nonscientific use of the word "auxin", and his research is shown to have been carried out in such a manner as to furnish no reliable results.

Wakeley, P. C. 618

1948 Physiological grades of southern pine nursery stock. Proc. Soc. Amer. For. 43: 311-322. fa

The grading rules generally used for classifying 1-0 planting stock of slash and longleaf pine are based on foliage, bud and bark development, and seedling size. It is shown that these morphological characters may be quite misleading, and the existence of physiological grades, based on ability to make new root growth and main-

tain water intake, is put forward. The possibility of (a) recognizing such grades, and (b) modifying them by special nutrition, differences in water tension under which seedlings are grown, and application of sprays, protective coatings, etc. at lifting time, are discussed.

WAKELEY, P. C. 619

1954 Planting the southern pines. Agric. Monogr. 19. 233 pp.

WAHLENBERG, W. G. 620

1929 Modification of western yellow pine root systems by fertilizing the soil at different depths in the nursery. J. agric. Res. 39: 137-146.

Ponderosa pine seedlings were grown in specially fertilized seedbeds to discover the effects of enriching the soil at different depths. Frequency curves show relative development of roots at various depths. The most desirable root forms for planting resulted where the rich layer was 6 to 10 inches deep. The experiment indicated the possibility of stimulating local root development at any desired depth, possibly by depositing fertilizer at the bottom of plow furrows. Root systems highly developed between 6 and 8 inches deep survived best in the field.

WAHLENBERG, W. G. 621

1930 Experiments in the use of fertilizers in growing forest planting material at the Savenac nursery. Circ. U. S. Dep. Agric. 125, 88 pp.

A triangle plot design was used to facilitate determination of the proportions N, K, and P most effective in attaining the desired form of root system. Fertilization in the forest nursery may overstimulate ponderosa pine planting stock and lead to lower survival in field plantations. In growing Engelmann spruce fertilization can save at least a year on the 5 or 6 year period needed to produce unfertilized seedlings of plantable size. The permanent need for fertilizer in forest nurseries, however, is to maintain the soil at a satisfactorily productive level. Sixty tests at Savenac are compared. The best results were obtained from a heavy treatment using a commercial mixture of superphosphate, bone meal, tankage, and guano containing 4.6 percent nitrogen and 9.8 percent phosphoric acid. A 2 to 1 ratio of dried blood and ground bone was nearly as effective, as

were other mixtures high in nitrogen. Field planting tests of fertilized stock are always advisable to check the degree of improvement in physiological quality achieved.

WALKER, L. C. 622

1955 a Foliar analysis as a method of indicating potassium-deficient soils for reforestation. Proc. Soil. Sci. Soc. Amer. 19: 233-236. A

Foliage analyses of native vegetation were found useful as a diagnostic aid in selecting tree species for planting on K-deficient soils in the Adirondack Mountains of New York. The K-deficient soils are sand plains of glacial outwash origin abandoned for cultivated crops in the 1920's. Exchangeable K in the plow zone averages 9 ppm., diminishing to 2 ppm. in the upper B horizon, and remaining constant to the B_3 at about 4 feet. Subsequent plantings of conifers exhibited abnormalities indicative of K deficiency where soil exchangeable K was less than 20 ppm.

Analyses of K in leaves of native vegetation showed a relationship to exchangeable K in the soil plow horizon for *Pinus strobus* (white pine), *Prunus virginiana* (choke cherry) *Fagus grandifolia* (American beech), *Populus tremuloides* (trembling aspen), *Fragaria virginiana* (Wild strawberry), and *Andropogon gerardi* (beardgrass). *Spartium scoparium*, a European legume, was the only cultivated plant to demonstrate a relationship.

Foliar K decreased as the season progressed for *Pinus strobus*, *Acer rubrum* (red maple), and *Prunus virginiana*.

Plots fertilized with KCl were analyzed for comparison. Exchangeable K, acid-soluble P, total N, organic matter, and pH analyses for soils are reported.

WALKER, L. C. 623

1955 b Influence of white birch in restoring potassium to deficient soils. J. For. 53: 451-452.

WALKER, L. C. 624

1956 Foliage symptoms as indicators of potassium deficient soils. For. Sci. 2: 113-120. A

Foliage symptoms of native vegetation indicative of soils deficient in K for normal growth of coniferous plantations are reported. The

study was conducted in the Adirondack Mountains of New York where deep coarse sands of fluvioglacial deposition occur extensively. Basic nutrients, particularly K, are rapidly leached from these acidic soils, resulting in a plow horizon average exchangeable K content of 9 ppm.

Pinus strobus (white pine) needle symptoms, described previously as short, chlorotic and often brown at tips, were observed. *Prunus serotina* (black cherry) exhibited bright red leaf margins with a well-defined demarcation to normal coloration. *Betula populifolia* (gray birch) leaves developed chlorosis in mid-August, beginning at the margins and proceeding inward. *Acer rubrum* (red maple) leaves are chlorotic throughout, but slightly more pronounced at margins. Leaflets of *Rubus Eubatus* spp. (blackberry) had marginal browning extending between veins, practically to the midrib.

Critical values for K concentration in mid-August-collected leaf tissue below which deficiency symptoms may be expected for these species are as follows:

Prunus serotina: 0.8 percent
Betula populifolia: 1.0 percent
Acer ruburm: 0.6 percent
Pinus strobus: 0.4 percent
Rubus subgenus Eubatus spp.: 0.8 percent
Spartium scoparium: 0.3 percent

Leaf analyses of K for July and August, and soil fertility data are presented. Plants fertilized with KCl were studied for comparison.

WALKER, N. 625

1955 c Response of black locust to phosphate fertilizer. J. For. 53: 844.

WALKER, R. B., S. P. GESSEL, AND P. G. HADDOCK 626

1955 Greenhouse studies in mineral requirements of conifers: Western red cedar. For. Sci. 1: 51-60. L

Seedlings of western red cedar, *Thuja plicata*, were grown in the greenhouse in sand and solution cultures in which the treatments included complete, minus Fe, minus B, low N, low P, low K, low Ca, low Mg, and low S. Young trees were grown also in pot cultures on forest soils to which various fertilizer additions were made. The periods of growth ranged from 6-24 months. Yields

were recorded and chemical analyses preformed on the foliage harvested from each experiment. The principle results were as follows:

1) The trees made excellent growth in culture solutions and sand cultures, reaching a height of 4½ feet in some instances. Growth was slower in soil cultures, probably because of leaching out of soluble N in the greenhouse watering.

2) Characteristic deficiency symptoms were observed for each of the elements studied and these are described in detail.

3) The chemical analyses make possible a comparison of the levels of the various elements found in normal foliage with those in deficient foliage.

4) Definite responses to N and P fertilization were observed in the pot culture experiments.

Some applications of experiments of this type of the production of trees in the field are discussed.

WALLACE, T. 627

1950 Trace elements in plant physiology. xviii + 159 pp., Chronica Botanica, Waltham, Mass.

WALLACE, A., ET AL. 628

1955 a Behavior of chelating agents in plants. Proc. Amer. Soc. hort. Sci. 65: 9-16.

WALLACE, A., ET AL. 629

1955 b Comparisons of fine chelating agents in soils, in nutrient solutions, and in plant responses. Soil Sci. 80: 101-108.

WALTER, R. 630

1953 Wood chips for mulching and humus. Shade Tree 26: 1-4. fa

Describes a method of composting hardwood chips used in New Jersey. The chips are dumped in the composting area and watered. When a sufficient quantity has accumulated, the chips are transferred into composting heaps, 6 ft. high, 5 ft. wide and any length. It is important that the width should not exceed 5 ft., so as to allow full access to the air. The heaps are depressed on top to hold water. An N-fertilizer solution is injected into the heaps with an ordinary feed-pipe until saturation is reached. The solution contains enough

$NaNO_3$ to supply *ca.* 2 lb./cu.yd. of packed wood chips. Watering with the same solution is repeated 4 weeks later and no further attention is necessary. The decomposition period varies with the season of the year and the size of the chips; chips from branches with foliage decompose quicker than those produced in the dormant season. For best results, summer chips should be composted for a year and dormant chips for about a year and a half. Notes are given on the use of the resulting compost.

WANDER, I. W. AND J. A. GOURLAY 631

1938 Available potassium in orchard soils as affected by a heavy straw mulch. J. Amer. Soc. Agron. 30: 438-446. BaA

Available K of soil under different systems of orchard culture was determined at 8 inch levels to a depth of 48 inches. The results indicated that available K was very high to a depth of from 24 to 32 inches beneath a heavy straw mulch where no K fertilizer had ever been applied. The trees had been under continuous mulch for 23 to 38 years, depending upon the orchard studied. The cultivated area was low in available K. Quick tests indicated that at the end of 10 years of K_2O application on an orchard in sod there had been a downward movement to a depth of 6 inches.

WAPPES, L. 632

1931 Wald und Holz. (Forest and timber) Vol. I. 872 pp. J. Neumann. Neudamn.

WASSINK, J. T. 633

1951 Kaligebrek bij diep overgestoven heidevelden (Potassium deficiency in heatherland covered by deep deposits of wind eroded material). Ned. BoschTijdschr. 23: 65-67. (Dutch) fa

Suggests an explanation of K deficiency in areas where deep layers of blown sand have covered former heathland. In soils liable to wind erosion, K is present in the form of feldspar and is readily leached from the upper horizons. Wind erosion first removes the K deficient horizons above the pan and deposits them in deep drifts elsewhere. If the pan is damaged, erosion may continue below it. The pan itself may break down but will not get blown until further disintegration has taken place, by which time some of its mineral content may have leached out. The K enriched pan detritus and/or the lower horizons containing a normal amount of K, will

generally be found, when displaced by the wind, to accumulate on the mounds or in the hollows of the original eroded area, and relatively small amounts will reach the area where drifts formed of the upper horizons have accumulated. Analyses of soil from (1) a mound on an eroded area, (2) the upper 5 cm. of a drift 6-7 m. deep, and (3) the upper 4 cm. of a wind-scooped area, confirm this explanation; (1) showed 14% and (2) and (3) only 8% potash feldspar. The difference is only slight, and practice shows that a single dressing of 300-400 kg. of 20% K salt per ha. will correct the deficiency.

WATTLE RESEARCH INSTITUTE 634

1953 Fertilizer experiments. Rep. Wattle Res. Inst. Univ. Natal. 1952-53: 26. fa

Gives results of applying N, P, K, and Ca at three levels to 2-to 3-year *Acacia decurrens* var. *mollissima* on sand, shale, and dolerite soils. The effect of liming was obscured by reduced frog hopper damage believed to be due to either higher light intensity or distasteful Ca in sap of limed plots. This matter is now under investigation.

WEATHERELL, J. 635

1953 The checking of forest trees by heather. Forestry 26: 37-40. faA

Experiments on podzolized heather moor at Allerston Forest have shown that a heather mulch applied round checked *Picea sitchensis*, *P. abies*, and *Chamaecyparis lawsoniana*, or more simply the elimination of living heather by surface hoeing, produces improved color and vigor of the trees. It has also been demonstrated that the addition of a nitrogenous fertilizer to checked Sitka spruce can, at least temporarily, alleviate the condition of check.

WEINKAUFF, R. 636

1941 Die Fortentwicklung der Forstwirtschaft durch N-Düngung (Further development of forestry by means of nitrogenous fertilizing). Forstwiss. Zbl. 63: 243-255. fa

On the basis of the available evidence, especially that obtained in Fabricius' investigation, the author argues that the productivity of German forests could be increased by nitrogenous fertilizing, should the need arise to make the country self-sufficient in timber.

Weis, F. 637

1927 Nogle Undersøgelser over Askens Krav til Jordbunden (Some investigations on the soil requirements of Ash). Dansk Skovforen. Tidsskv. 12: 282-355. (Danish)

Weis, F. 638

1933 Beplantningsforsøg paa et afføget sande Haarup sandflugt ved Silkeborg (Planting experiments in a territory of drift sand. Haarup drift sand near Silkeborg). Dansk Skovforen. Tidsskr. 13: 63-112. (Danish)

Wenger, K. F. 639

1953 The effect of fertilization and injury on the cone and seed production of loblolly pine seed trees. J. For. 51: 570-573. fa

Partial girdling of seed trees had no effect on seed production. A single application of 25 and of 50 lbs. of complete fertilizer, spread around the tree to 2 ft. beyond the edge of the crown, significantly increased cone production in 25-year-old but not in 40-year-old seed trees.

West-Nielson, G. and O. Oksbjerg 640

1954 Om rodfordœrverangreb. II (Damage to spruce by *Fomes annosus*. II. Hedeselsk. Tidsskr. 74: 336-343, 347-352, 75, 72-81. (Danish)

White, D. P. 641

1941 Prairie soil as a medium for tree growth. Ecology 22: 398-407. aA

Chemical and biological aspects of Wisconsin prairie soils were investigated in the laboratory and greenhouse with respect to their effect upon tree growth. Results showed that the early development of both conifers and hardwoods is adversely affected by some inherent deficiency of the prairie soils irrespective of the environmental conditions. Pot culture experiments showed that seedlings of red ash, green ash, and American elm responded to fertilizer treatments on prairie soils, but even the application of a complete fertilizer including minor elements, produced yields on prairie soils only half as great as were produced on untreated forest soils. Red and white pine seedlings raised on virgin prairie soils failed to develop mycorrhizae. Results of this study suggest that mycorrhizae

do not merely increase the availability of difficultly soluble nutrients, but exert a specific growth promoting effect upon forest seedlings. The lack of this growth promoting action appears to be a major condition inhibiting the growth of trees on prairie soils in which mycorrhizal forming organisms are absent.

WHITE, D. P. 642

1950 The effect of nursery soil fertility on the resistance of jack pine (*Pinus banksiana* Lamb.) seedlings to adverse environmental and biotic factors. Ph.D. Thesis. Univ. Wis. Library, Madison. A

The initial phase of this study was concerned with gravimetric ratios, chemical composition of needle, stem, and root tissues of seedlings collected from natural reproduction plots, seed beds in various nurseries, fertilizer treated plots, and greenhouse cultures. The highest needle-stem, and needle-wood ratios were obtained in seedlings from natural reproduction, and the lowest ratios from seedlings grown on heavily fertilized soils. The determination of essential plant nutrient elements in seedling tissues revealed a close correlation between the chemical composition of stems and needles and the balance of soil nutrients. Application of fertilizers decreased the contents of ether and alcohol-benzene extractibles and protein in all parts of the seedlings. This relationship, however, was reversed in needle tissue collected in mid-summer. Seasonal maximums of both mineral constituents and organo-solubles occurred in spring stem tissue and fall needle tissue.

The rate of desiccation of seedlings, produced under different levels of fertility, was observed by placing the trees in solutions of different osmotic concentrations of sucrose. The results indicated that seedlings produced with heavy applications of complete fertilizer had the greatest initial resistance to plasmolysis. Nitrogen forced seedlings and seedlings produced on unfertilized soils had the same low degree of resistance against plasmolysis in spite of great differences in seedling size.

Survival counts of seedlings planted under adverse field conditions showed the greatest mortality of stock raised with one-sided nitrogen fertilization. Seedlings produced with applications of complete fertilizer were better able to survive under adverse field conditions, than those grown without fertilizer.

The toxicity of the hot water extract from seedling roots to root-rot fungi was investigated in pure cultures. Two and one-half

per cent aqueous extracts from the stock raised under different conditions were incorporated with malt agar in culture tubes and inoculated with *Polyporus Schweinitzii*. The presence of substances toxic to the growth of the organism in the roots of jack pine was demonstrated. Root extracts from seedlings raised with heavy applications of fertilizer had the slightest depressing effect on the growth of the test organism. Extracts from seedlings produced with unbalanced nitrogen fertilization showed the greatest initial inhibitory effect on fungal growth. This effect, however, diminished after a few days of incubation, probably due to an antidotic interaction of the medium.

Insect feeding trials were carried out in caged pot cultures with selected populations of the red-headed pine sawfly.

Sawfly larvae were not disposed to feed on the juvenile needles of one-year-old pine, and seemed to be repelled by the nitrogen forced stock. However, trials with two-year-old seedlings resulted in dramatically different degrees of preference, as evidenced by the amount of feeding, content of frass, and development of the larvae. Equal numbers of larvae rapidly defoliated seedlings of natural reproduction, whereas, fertilized nursery stock suffered moderate or very slight injury. Nursery stock raised with unbalanced nitrogen fertilization suffered comparatively greater damage. All of the larvae feeding on nursery stock died prematurely, convulsions preceding the death.

On the basis of this study it is concluded that unreasonably high level of nursery soil fertility, disrupted ratio of nutrients, and unreasonably high content of nitrogen are conducive to the production of nursery stock vulnerable to drought, fungus diseases, and attacks by parasitic insects.

WHITE, D. P. 643

1954 Foresters test aerial application of fertilizers. Proc. nat. Comm. Fert. Appl. 30: 69-70.

WHITE, D. P. 644

1956 a Aerial application of potash fertilizer to coniferous plantations. J. For. 54: 762-768. A

One hundred acres of pine and spruce plantations on coarse sandy outwash soils of the Adirondack province of New York were fertilized in early summer of 1954 with granular muriate of potash fertilizer (60%, KCl). Material was applied by Stearman 1B75A

aircraft with plastic-lined front cockpit hopper and Venturi split tail Transland spreader. Calibration technique is described and detailed flight statistics are reported. Required application rate of 200 lbs. per acre (± 50 lbs.) was satisfactorily achieved. Estimated cost of treating similar areas is 9 to 13 dollars per acre. Contents of soil and foliar potassium before and after treatment are reported and reflect significant uptake and satisfactory distribution of material. Improved growth of trees following treatment was indicated by better color and increased needle length after a single growing season.

WHITE, D. P. 645

1956 b The need and the promise of fertilizers in forestry. Plant Food Rev. 2(4): A

A popular report on the historical background for prejudice against the use of fertilizers in forestry practice and a discussion of recent research and economics trends which have greatly changed the outlook toward fertilizer usage.

WIEDEMANN, E. 646

1931 Die Düngung im Forstbetrieb (Fertilizers in forest management). InF. Honcamp: Handbuch der Pflanzenernährung und Düngerlehre 2: 813-841.

WIEDEMANN, E. 647

1932 Der gegenwärtige Stand der forstlichen Düngung (The present status of forest fertilization). Arb. dtsch. LandwGes. 385.

WIEDEMANN, E. 648

1934 Über die Beziehungen des forstlichen Standortes zu dem Wachstum und dem Wirtschaftserfolg im Walde (Relation of site to growth and successful forest management). Dtsch. Forschung 34: 5-103.

WIELER, A. 649

1938 Über die Einwirkung von Bley- und Zinkverbindungen auf Wachstum und Entwicklung von Kulturpflanzen (The action of lead and zinc compounds on the growth and development of plant cultures) Mitt. Forstwirt. Forstwiss. 9: 175-191.

In acid moor soil, addition of Pb minerals did not hinder growth of spruce and pine seedlings, and in some instances favored growth of pine. Oak and beech seedlings were injured by lead. In slightly acid heath soil growth of spruce was hindered by white lead and metallic Pb, and all Pb compounds were harmful when the soil was made alkaline by liming. The growth of certain plants in alkaline soils was retarded by some compounds and not by others, while other plants reacted differently in the same soil. Root growth of spruce and pine was stimulated by addition of 0.16-0.26% Pb. Addition of 1-2% Pb reduced growth of spruce roots, but did not affect pine. Zn retarded growth of crop plants when more than 0.16-0.19% was present in garden soil with alkaline reaction, or more than 0.4-0.16% in acid soil. The harmful effect can be partly offset by addition of lime.

WILDE, S. A. 650

1936 Preparation and use of composted fertilizers in forest nurseries. Tech. Notes Wis. Conserv. Dep. 12.

WILDE, S. A. 651

1937 a Selection of forest litter, duff, and humus for use in forest nurseries. Tech. Notes. Wis. Conserv. Dep. 16.

WILDE, S. A. 652

1937 b The use of liquid humate fertilizers in forest nurseries. J. For. 35: 388-392. L

The purpose of this article is to call the attention of foresters to a simple and yet highly efficient method of improving the growth of inferior nursery stock by application of liquid humate fertilizers.

WILDE, S. A. 653

1938 Soil-fertility standards for growing northern conifers in forest nurseries. J. agric. Res. 57: 945-952. fa

Based on the knowledge that productive forest soils will produce at least one crop of vigorous seedlings of the species that originally grew on the area, detailed study was made of the soils under productive stands of *Pinus banksiana*, *P. resinosa*, *P. strobus*, *Picea glauca*, *Abies balsamea*, and also mixed northern hardwoods. Analyses were made for pH value, exchange capacity, total and

available nitrogen, available phosphorus, available potash, and replaceable bases. Standards for the maintenance of fertility in coniferous nursery soils were established by statistical treatment of the data so obtained. The analyses of virgin soils showed that the nitrogen: phosphoric acid: potash ratio is about 1:2:5. It is pointed out that soil improvement does not mean merely the addition of a certain amount of organic matter and mineral fertilizers. A period of physiological and biological activity is necessary to incorporate the required materials into the soil complex. General directions for the adjustment of soil conditions are outlined.

WILDE, S. A. 654

1946 a Soil fertility standards for game food plants. J. Wildlife Mgtmt. 10: 77-81.

WILDE, S. A. 655

1946 b Difficultly soluble sources of nutrients; their use in forest nurseries. J. For. 44: 1082-1086. faA

The availability of difficultly soluble plant nutrients was studied in sub-irrigated pot cultures, using jack pine, red pine, white spruce, yellow birch, and white elm as indicators. Applications of raw acid peat, rock phosphate, and feldspar to a soil deficient in nutrients, greatly improved the growth of seedlings, but failed to produce stock large enough to satisfy nursery standards. Stock of adequate size was produced by means of supplementary treatment of the soil with liquid fertilizers or by the addition of hardwood/hemlock duff. The addition of dolomitic limestone depressed the growth not only of acidophilous conifers and yellow birch, but also of lime-tolerant white elm. This indicated that the depressing effect of the limestone was due to stimulation of cellulose decomposers which consumed most of the available nitrogen. The application of difficulty soluble fertilizers was found to be desirable as a means of reducing the concentration of the soil solution, but the success of such treatments is likely, in many instances, to depend upon supplementary use of readily soluble fertilizers in solution, or composts and catch crops.

WILDE, S. A. 656

1946 c Forest soils and forest growth. xx + 241 pp., Chronica Botanica, Waltham, Mass.

WILDE, S. A. 657

1956 Use of fertilizer for improvement of forest stands and plantations. Tech. Note Wis. Conserv. Dep. 54: 7 pp. L

The use of fertilizers in forestry practices throughout the world are briefly discussed. The writer acknowledges the wide spread interest in the use of fertilizer materials of one kind or another are becoming entrenched in forestry practices; but the success of fertilizer treatments of forest stands achieved in certain cases does not mean that the large scale use of fertilizers in silviculture is free from formidable problems. Some of these problems, e.g., the economic soundness of treatments and mechanization of the application procedure hold promise of comparatively easy solution. The most difficult task concerns the capacity of different soils to transmit the effects of fertilizer treatments to the growing stock. This capacity is the result of several conditions including the supply of soil water, air and nutrients, the humidity of climate, and the length of the growing season.

The second part of this paper concerns the work being conducted by the University of Wisconsin in fertilizer treatments in forestry. Three modified procedures of fertilizer placements are now being investigated: (1) cultivation of legume crops prior to tree planting, (2) localized application of slowly available fertilizers at time of tree planting, (3) broadcast application of readily soluble fertilizers in stands and plantations of advanced age.

WILDE, S. A., ET AL. 658

1952 Characteristics of nursery stock related to its resistance against adverse environmental factors. Tech. Note Wis. Conserv. Dep. 47.

WILDE, S. A., ET AL. 659

1956 The effect of green manuring on the growth of pine plantations. Tech. Note Wis. Conserv. Dep. 53. 3 pp. L

As a result of encouraging reports from Europe on the use of green manure crops, similar experiments were initiated in Wisconsin in 1945. The areas were treated with approximately two tons of limestone, 300-500 lbs. of 0-9-27 per acre, seeded to inoculated legumes which were harvested two years later. Then the area was planted to red pine. The results of trials indicated that the survival and growth of trees on many fertilized plots failed to fulfill ex-

pectations. The reason why the trials failed in Wisconsin is the invasion of weeds on fertilized areas and their subsequent competition with trees for moisture and nutrients. It is entirely possible that upon closing the canopy and suppression of weeds, the rate of tree growth will become better on the fertilized plots.

WILDE, S. A., W. H. BRENER, AND C. J. KRUMM 660

1946 Types of composted fertilizer used in forest nurseries. Proc. Soil Sci. Soc. Amer. 11: 508-510. a

Investigation of different types of composts ((1) fermented composts, (2) partly activated composts, and (3) inert composts) in regard to their fertilizing value in forest nurseries, discussing advantages and disadvantages of each as result of several greenhouse trials.

Fermentable organic matter, especially forest litter and duff, play important part in the preparation of composted fertilizers. The use of any one of the three compost types, supplied with identical contents of mineral fertilizer, is likely to produce nursery stock of widely different morphological and physiological characteristics, thus the resulting growth of the stock cannot be wholly attributed to the supply of available nutrients present.

WILDE, S. A. AND H. H. HULL 661

1937 Use and function of peat in forest nurseries. J. Amer. Soc. Agron. 29: 299-313. L

Three chemical properties of decisive importance in selection of peat for use in forest nurseries are reaction, base exchange capacity, and total N content. Peat with a pH of 5.5 or less is most desirable in nurseries, especially those raising coniferous stock. Peat with a pH of 6.0-7.0 may be satisfactory in hardwood stock production, but undesirable for raising conifers due to damping-off disease. Peat having a total N content of 2% or more is considered a very satisfactory source of N, but peat with total N content less than 1% is a low source of N. A base exchange capacity of peat of 80 me./100 g. appears to be the allowable minimum while a capacity of 100 me./100 g. is quite satisfactory.

WILDE, S. A. AND S. KLIMAN 662

1931 (Modern trends in forest nursery practice in the United States). Lesn. Pracé 10: 305-315. (Czech with English summary)

WILDE, S. A. AND J. C. KOPITKE 663

1940 Base exchange properties of nursery soils and the application of potash fertilizers. J. For. 38: 330-332. L

Practically all available potash in the soil is in the form of an exchangeable ion and so the quantity of unleached potash is directly dependent on the base exchange capacity of the soil. The greater the exchange capacity of nursery soils, the greater the average level of available potash retained against leaching, the greater rate of application of potassium chloride or potassium sulphate fertilizer may be suggested.

Catch crops, composts and liquid fertilizers are used to increase the potash content of nursery soils having a low base exchange capacity, and soil exchange capacity may often be increased by applications of peat or similar materials.

WILDE, S. A. AND C. J. KRUMM 664

1941 Value of manure as an ingredient of composted fertilizers. Tech. Notes Wis. Conserv. Dep. 23. 7 pp.

WILDE, S. A. AND C. J. KRUMM 665

1946 Allowable concentration of commercial fertilizer salts in composts used in forest nurseries. J. For. 44: 662-665. faA

The effect of concentration of commercial fertilizer salts in nursery composts upon microorganisms and higher plants was studied, using direct counts of bacteria and fungi, the Cunninghamella plaque method, and pot cultures with buckwheat and *Pinus resinosa*. The results indicate that 50-60 lbs. of total fertilizer salts per cu. yd. of composted organic matter is an average desirable concentration. Composts carrying less than 25 lbs. of salts per cu. yd. were found to be uneconomical. Composts with a concentration of salts exceeding 80 lbs. per cu. yd. suffer considerable losses of nutrients, especially potash, by leaching, may become unbalanced, and present danger of chemical injury to nursery stock.

WILDE, S. A., C. J. KRUMM, AND W. H. BRENER 666

1946 Composted fertilizers: Their properties and preparation for use in nurseries. Tech. Notes Wis. Conserv. Dep. 25. 9 pp.

WILDE, S. A., O. G. NALBANDOV, AND T. M. YU 667

1948 Ash protein and organic-solubles of Jack pine seedlings in relation to soil fertility. J. For. 46: 829-931. fa

Two-year-old jack pine seedlings from natural reproduction on sandy outwash soils and from heavily fertilized nursery beds were analyzed for their contents of ash, crude protein, essential oils and other volatile substances, ether extractibles, and alcohol/benzene extractibles. Statistical treatment of the results showed that fertilizer-forced seedlings have a significantly higher content of ash and protein, and a significantly lower content of alcohol/benzene extractibles. A considerable portion of the alcohol/benzene soluble fraction consists of tannin and other disinfecting compounds, and it is suggested that the low concentration of this fraction in nursery stock may be directly correlated with their greater susceptibility to parasitic organisms. The ash/protein ratio of the tissue may serve as an indicator of the balance of nursery-soil fertility and the desirable proportion of fertilizers to be applied.

Wilde, S. A. and W. E. Patzer 668

1940 Soil fertility standards for growing northern hardwoods in forest nurseries. J. agric. Res. 61: 215-221. BaA

The soils under productive stands of representative hardwood species (*Betula lutea*, *Acer saccharum*, *Tilia americana*, *Ulmus americana*, and *Fraxinus americana*) were analyzed for pH value, base-exchange capacity, total and available N, available P, and replaceable bases. The average values obtained by statistical treatment of the results are suggested as standards for the maintenance of fertility in hardwood-nursery soils. Analyses of soils showed that the $N/P_2O_5/K$ ratio lies near 1-2-5 for yellow birch and 1-3-5 for the rest of the hardwood species studied.

Wilde, S. A. and R. O. Rosendahl 669

1945 Value of potassium feldspar as a fertilizer in forest nurseries. J. For. 43: 366-367. fa

Experiment has shown that ground orthoclase feldspar is a suitable source of potassium for jack pine and red pine seedlings raised in quartz sand cultures; the planting stock used was obtained from nursery beds at the age of seven weeks and was profusely inoculated with mycorrhizae. Application of ground feldspar at the rate of three tons per acre provided sufficient potassium to maintain a satisfactory rate of growth of seedlings of both species.

The use of feldspar and other potash-bearing minerals or rocks to replace commercial potash fertilizers in forest nurseries has ad-

vantages in economy and in reducing the fluctuation of soluble salts in nursery soils.

However, as the concentration of potassium in the tissues of feldspar-grown seedlings is considerably lower than in seedlings produced with potassium chloride, it is suggested that in regions subject to frost damage the application of potash-bearing rocks should be supplemented with light treatments of readily soluble potash salts, applied either broadcast or as a liquid fertilizer.

WILDE, S. A., F. B. TRENK AND A. R. ALBERT 670

1942 Effect of mineral fertilizers, peat, and compost on the growth of red pine plantations. J. For. 40: 481-484. faA

The effect of commercial fertilizers, various peats, and composts upon the survival and growth of red pine (*Pinus resinosa*) plantations has been investigated on a depleted outwash sandy soil. Fertilizing materials were applied either broadcast prior to planting, or in the planting holes. Applications of fertilizers exerted no significant beneficial effect upon the survival of seedlings. Heavy applications of peat, compost, and commercial fertilizers decreased appreciably the survival of planted trees. The ill effects are believed due to the injury of planting stock by salts in solution, increased competition of weeds, and the decrease in the content of available water by organic remains of high hydroscopicity. The maximum average increase in height growth, achieved in broadcast fertilization, was about 30 percent; the maximum increase in average height in localized application of fertilizers did not exceed 12 per cent. Alkaline peat and horse manure depressed the growth.

The results obtained with the most successful treatments of red pine plantations hardly justify the cost of fertilizers and extra labor. The failure of the plantations studied to respond appreciably to fertilizer treatments, even on a depleted sandy soil, it attributed primarily to the high "nutrient-utilization efficiency" of this species. A warning is given against fertilizer treatments of plantations on soils in which a radical nutrient deficiency has not been clearly established.

WILDE, S. A. AND G. K. VOIGT 671

1948 Specific gravity of the wood of jack pine seedlings raised under different levels of soil fertility. J. For. 46: 521-523. faA

The specific gravity of stem tissue was determined in two-year old jack pine seedlings grown under two widely different levels of soil fertility. The volume of stem sections was determined by the use of the Brial mercury volumeter, and their weight on an analytical balance after drying for one hour at 105°C. Seedlings obtained from natural reproduction on cut-over, coarse, sandy soil showed considerably higher specific gravity of wood than seedlings produced on heavily fertilized nursery beds (0.41 and 0.23, respectively, for average stems). The relation of the specific gravity of seedlings to their resistance against drought, sun-scorch, frost, winter injury, snow-press, sleet and parasites is pointed out. The determination of specific gravity is suggested as a means of the evaluation of nursery stock.

Wilde, S. A. and G. K. Voigt 672

1952 Determination of color of nursery stock foliage by means of Munsell color charts. J. For. 50: 622-623.

Wilde, S. A., F. G. Wilson and D. P. White 673

1949 Soils of Wisconsin in relation to silviculture. Publ. Wis. Conserv. Dep. 525-549. Madison. 171 pp.

Wilde, S. A. and R. Wittenkamp 674

1939 The phosphate and potash starvation of forest seedlings as a result of the shallow application of organic matter. J. For. 37: 333-335. fa

A series of experiments show that the application of top dressings to nursery soil tend to arrest the downward extension of the seedling root systems and thus deprive them of important nutrients, mainly phosphate and potash, which are present in the soil at a greater depth. Alternate ploughing and disking, or roto-tilling are recommended to prevent this condition.

Wilde, S. A., R. Wittenkamp, E. L. Stone, and H. M. Galloway 675

1940 Effect of high rate fertilizer treatments of nursery stock upon its survival and growth in the field. J. For. 38: 806-809. faA

Nursery soil of average fertility was given heavy applications of a balanced nitrogen/phosphorus/potash fertilizer, at rates up to

1,100 pounds per acre total salts, the fertilizer being applied broadcast and in solution. Two-year-old jack pine, red pine, and Scotch pine seedlings from fertilized and check plats were transplanted on podzolic outwash sandy loam. An average increase in survival of fertilized stock varied from 10 to 15 percent, at the end of the third growing season for jack pine and the end of the second season for Scotch and red pine, but this was not considered significant owing to the variability among individual sample plats. The average increase in height growth varied from 20 to 30 percent in favor of fertilized stock, and was found to be statistically significant. Spring planting resulted in somewhat better survival and height growth than the fall planting.

WILDE, S. A. AND R. WITTENKAMP 676

1942 Duff briquette fertilizers: their preparation, use, and effect upon the growth of trees and other plants. J. Amer. Soc. Agron. 34: 736-746. fa

Briquettes are made of a mixture of partically decomposed hardwood hemlock forest litter and acid Lacustrine clay treated with a solution of ammonium sulphate, potassium nitrate and ammonium phosphate. Their use with ornamental trees and shrubs, nursery beds, berries, truck crops and flowering plants gave satisfactory results and the favorable effect was greatly increased under conditions of artificial watering. The beneficial effect of the briquettes is partly due to the release of growth-promoting substances (vitamins and hormones), which are particularly effective in improving the growth of forest vegetation on quartz sand or on prairie soils.

Results from the fertilization of forest plantations on cut-over lands varied widely. An appreciable increase in the rate of tree growth was observed only on soils which were radically deficient in certain nutrient elements, depleted in organic matter, or had not previously supported forest vegetation. Pines and other light-demanding pioneer species on fairly productive sandy soils showed only a small average increase in height growth due to fertilization with briquettes.

WILSON, C. C. 677

1953 The response of two species of pine to various levels of nutrient zinc. Science 117: 231-233. a

Investigations with full nutrient solutions in sand cultures indicated that loblolly and shortleaf pine required the same amounts

of Zn (0.1 ppm.) for normal growth as previously reported for *Pinus radiata* in Australia. Loblolly seedlings (*P. taeda*) appeared to be less susceptible to Zn deficiency than were short-leaf seedlings (*P. echinata*), and deficiency symptoms in both closely resembled those described for littleleaf disease.

WITTICH, W. 678

1942 Die Aktivierung von Rohhumus extrem ungünstiger Beschaffenheit. (The activation of raw humus of extremely unfavorable quality). Z. Forst-u. Jagdw. 7: 8. A

As a result of a naturally produced unharmonious distribution of nutrients (strong predominance of potassium and magnesium in contrast to calcium) extremely unfavorable forms of raw humus are found on certain soils in Germany which do not permit biological activation by normal means. A pronounced stunted growth of the forest is the result.

A fertilization with lime in combination with a leguminose crop or mineral nitrogen eliminated in the shortest time the growth stagnation and a higher yield class was attained by the stand.

The worst raw humus covers can also be biologically activated in this way which exercise then a very favorable influence on the soil and plants.

The artificial removal of such raw humus which used to be common practice is no longer justified at the present.

WITTICH, W. 679

1950 Die Düngung der Fichtenkulturen (The fertilizing of spruce plantations). In: H. Hesmer (ed.), Die Technic der Fichtenkultur: 25-42. M. and H. Schaper, Hannover.

WITTICH, W. 680

1952 a Significance and basic principles of lime manuring in the forest. Coedwigwr. 1: 11-18 A

Practical experience of the former Prussian Forest Research Station gave undeniable evidence of the beneficial influence of liming on base poor soils with a cover of raw-humus. In experiments carried out by the Research Institute at Hann.-Münden, liming of spruce forest soils gave growth increases of 20-30%, maintained even after 18 years. Lime manuring supplemented sometimes by other ameliorative measures makes possible, in many cases, the

establishment of certain biologically active hardwoods on soils where they would not previously succeed. The stage at which liming is to be carried out is determined by the nature of the humus transformation required viz. mineralization or conversion into stable true humus. In recently cleared areas the products of a rapid mineralization of the raw humus may be too abundant to be fully utilized by the young plantation and it may be better to reactivate before felling. Alternatively the raw humus may be converted into more stable true humus and this may be achieved by liming. In Hassenkamp's experiments at Syke, mixing of the raw humus with the mineral soil followed by the application of lime (at 3000 kg./ha.) + P + K and the cultivation of legumes, resulted, in the course of a few years, in the conversion of 60% of the organic matter into valuable nitrogenous stable humus substances.

WITTICH, W. 681

1952 b Der heutige Stand unseres Wissens und neue Wege zur Lösung des Rohhumusproblems im Walde (The present state of our knowledge and a new solution to the raw humus problem in forestry). SchrReihe forstl. Fak. Univ. Göttingen 4: 106 pp. A

After a description of the present state of humus research, with special consideration of the conditions in the forest, the effects were examined, which several fertilization measures, in combination with certain cultivation methods, have on the transformation of an unfavorable raw humus cover.

The efforts were above all concerned with the discovery of methods to control the transformation in such a way that possibly a larger part of the raw humus is changed into valuable and stable humus substances. It was shown that this is possible when certain conditions are adhered to. The changes and properties of the humus are dealt with in detail (contents of humic acid and its compositon, nitrogen content, changes in the distribution of the various forms of nitrogen, in particular of -amino-nitrogen and heterocyclicly fixed nitrogen, absorption capacity, etc.).

WITTICH, W. 682

1954 Die Melioration streugenutzter Böden (Fertilization of stands after litter removal). Forstwiss. Zbl. 7: 8. A

Continuous litter removal has caused a serious loss of humus from the soils and a relative enrichment of difficultly decomposable ni-

trogen, in particular heterocyclicly fixed nitrogen, so that a pronounced deficiency of availabe nitrogen exists.

The serious growth stagnations on these sites can be readily cured by means of a nitrogen fertilization in the form of legumes. The production of such crops can be promoted by other fertilization measures. At the same time a restoration of the remaining humus takes place. The amino-nitrogen, more than the more resistant heterocyclicly fixed nitrogen is responsible for the newly formed nitrogen. A retrogressive development also sets in in face of the processes, under the influence of litter removal. The same applies to the restoration of humic acids.

WITTICH, W. 683

1954 Arbeitstechnische Methoden der Forstkalkung (Methods of liming in the forest). Forst u. Holz. 9A: 142-144. fa

Describes and illustrates various types of German equipment of proved use.

WITTICH, W. 684

1956 50 Jahre Ebnath (50 years Ebnath) Forstwiss. Zbl. 5: 6. A

Serious biological disturbances in the soil and stunted growth of the forest trees occur on phyllitic shaly soils, where there is an excessive uptake of potassium and magnesium ions by the plants and insufficient calcium absorption.

Already a weak fertilization with lime in combination with an application of nitrogen was found to have a lasting effect when the presently 40-50 year old soil improvement area was again examined. This applies both to the elimination of the biological disturbances in the soil and the regulation of the ion-ratios in the needles of the forest trees as well as the disappearance of the growth disturbances of the forest.

WOLFE, L. P., JR., AND S. DUNN 685

1953 Sawdust composts in soil improvement. I. Studies on aeration, acid hydrolysis, manure, and waste materials as composting aids. Plant and Soil 4: 223-234. L

Different sawdust mixtures with cow manure and soil were composted in bins with aeration for three years. Rotted wood was also tested. Through greenhouse pot culture trials it appears that

moisture is a very important factor in decomposing sawdust and that normal precipitation may not be enough.

Various mixtures of sawdust with hen manure and fresh grass silage were prepared and allowed to stand for five months. Through greenhouse pot culture trials it appears that some mixtures have promise of being good growth media, especially the hen manure, green vegetation, and sawdust combinations.

The use of acid-hydrolysis and steam as a means of sawdust decomposition is not an effective method for producing good growing media for plants.

Fish waste mixtures with sawdust composted in jars indoors gave rapid breakdown of the sawdust, but the resulting materials undiluted with soil did not produce good plant growth.

Comparisons were made of the urea to nitrate as a source of nitrogen in growing plants in soil with and without sawdust. Plants grown in pot cultures of such mixtures gave higher yields with nitrates.

Worley, C. L., H. R. Lesselbaum and T. M. Matthews 686

1941 Deficiency symptoms for the major elements in seedlings of three broad leaved trees. J. Tenn. Acad. Sci. 16: 239-247. fa

Deficiency symptoms for the elements Ca, K, Mg, S, P, N, and Fe, and the effects of deficiency on general plant development, are reported from sand-culture experiments with seedlings of *Ulmus pumila, Ailanthus altissima,* and *Catalpa speciosa.*

Wyman, D. 687

1933 a Growth experiments with shade trees. Proc. nat. Shade Tree Conf. 9: 37-41.

Wyman, D. 688

1939 b Growth responses of pin oaks due to fertilizers, pruning, and soil conditions. Proc. Amer. Soc. hort. Sci. 29: 562-565. BaA

200 pin oaks 6 ft. high were planted in the fall of 1930. The experiments were duplicated on 2 entirely different soil types, and all experiments were repeated in the spring of 1931. Lawn conditions were maintained on all experiments to find out easy methods for

treating young shade trees in order to get quick growth. Even the 2nd growing season (1932) after spring transplanting, those trees loosely or roughly planted grew less than the carefully planted trees. Fertilizers applied at the rate of 8 ozs. of $(NH_4)_2SO_4$ or 12.6 ozs. of ammo-phos per tree increased growth markedly the same year. The leaves of fertilized trees were notably darker green. From applying fertilizer all at once, varying injury resulted to the trees depending on the soil type; when the same total amount was added in smaller amounts at intervals, no injury whatever resulted. Some of the results on pruning are apparent the 2nd year, but conclusive proof of their effectiveness can not be secured until these results prove consistent.

WYMAN, D. 689

1938 Recent developments in the Cornell shade tree experiments. Proc. nat. Shade Tree Conf. 10: 111-114.

WYMAN, D. 690

1936 Growth experiments with pin oaks which are grown under lawn conditions. Bull. Cornell agric. Exp. Sta. 646: 1-23. Ba

When applied in March, before the grass had begun its growth, amounts as high as 50 lbs. of $(NH_4)_2SO_4$ per 1000 sq. ft. of lawn could be used on the soils in question, without injury. Pin oaks, some of which were planted Nov. 1, 1930, and some in the spring of 1931, were fertilized with $(NH_4)_2SO_4$ or ammo-phos applied in crowbar holes surrounding the trunks. The time of planting had a marked effect on survival, for approximately twice as many trees were killed or injured in the fall as in the spring groups. Careful planting methods in which the soil at the bottom was loosened, the roots placed, and the soil firmed with the feet were found more important in spring than in autumn planting. Pruning trials showed higher mortality among trees left unpruned at the time of transplanting than for pruned trees. Trees with branches left along the trunk made significantly more growth in their 2nd and 3rd years than those pruned of all lower branches. Fertilizer applied in split amounts to young pin oaks proved safer than single applications. N and P in the form of ammo-phos produced greater growth than did N alone. When increases in diameter were greater than 0.5 cm. per year, there was a high correlation between diameter increment and twig elongation. In a group of unfertilized trees, large growth one year was not necessarily correlated with large growth the next.

Young, H. E. 691

1938 The acidification of alkaline nursery soils for the production of exotic pines. Qd. agric. J. 50: 585-600. fa

Describes experiments at Yarraman (Southern Queensland) in the application of varying quantities of ground sulfur. The relatively best development in *Pinus caribaea* seedlings, as judged by highest survival, maximum average height, and most satisfactory mycorrhizal development, was obtained after treatment of the soil of the seedbed with 1½ lbs. of sulphur to every 12 sq. ft.

Young, H. E. 692

1940 Fused needle disease and its relation to the nutrition of Pinus. Part B. The mycorrhizal theory regarding the cause of fused needle disease. Qd. agric. J. 53: 374-392.

Young, H. E. 693

1948 The response of loblolly and slash pine to phosphate manures. Qd. J. agric. Sci. 5: 77-105. fa

Describes experiments to test the response of *Pinus taeda* to various levels of soil phosphate. Different treatments were given to experimental plots in 1939, four levels of superphosphate being added to the soil, with one control. Measurements of d. b. h. and height were made annually and analyses for P content of soil were done in 1939, 1943, and 1946. As a measure of soil P content the total P value of a sample taken from the top 4 in. of soil was used. An application of 818 lbs./acre of superphosphate was found most suitable, since it produced the greatest diameter increment and the largest profits both from merchantable thinnings and total volume. Rock phosphate was found to be as efficient as superphosphate and is much cheaper. Analyses were also made of P content of needles of *P. taeda* and *P. caribaea* in treated plots and results are correlated with growth increment and soil P values. The use of a needle P factor in determining the requirements of trees for P is described and discussed.

Youngberg, C. T. 694

1955 Effect of soils on the establishment of tree crops. Proc. Soil Sci. Soc. Amer. 19: 86-90.

YOUNGBERG, C. T. AND R. C. AUSTIN 695

1954 Fertility standards for raising Douglas-fir in forest nurseries. J. For. 52: 4-6. BaA

Fertility standards for the production of balanced Douglas fir nursery stock were established by analyzing the surface soils from productive Douglas fir stands in Oregon and Washington. Preliminary fertilizer trials in the Forest Industries Nurseries, Nisqually, Washington, and subsequent out-planting of the stock produced gave positive results.

ZEHETMAYER, J. W. L. 696

1951 Experiments in planting of upland heath. Rep. For. Res., Lond. 1949-50: 27-33. fa

A brief review is given of a number of old experiments, the results of which are being prepared for publication. Ground preparation for planting is mentioned, describing the stages leading up to the current procedure of deep single-furrow ploughing, the beneficial effects of which are largely attributable to the suppression of heather by the spoil. Best results are obtained by planting in the furrow bottom. Nurse crops and mixtures are mentioned. Difficult species such as Douglas fir, Sitka spruce, and *Tsuga* can often be successfully established by using broom or some species of pine as a nurse crop from the start. Manuring at the time of planting has clearly indicated the advantage of using both phosphates and N on the poorest heath types, even for pines. Recent work on planting 1-year seedlings has given rather variable results: in favorable seasons, outstandingly successful establishment of plantations has been achieved very cheaply, and even in bad seasons the total cost of planting with seedlings followed by replacement of up to 30% casualties, may be cheaper than complete initial planting with transplants.

Historical reports on heath land experiments at Hamsterly and Allerston forests are briefly reviewed, and a note on an investigation into the causes of failure of Sitka spruce to grow properly on certain sites at Clachindarroch Forest (W. Aberdeenshire), is given, together with recommendations for treating the various ground types where initial planting had failed to yield a crop.

ZEHETMAYR, J. W. L. 697

1953 Problems of moorland afforestation. Quart. J. For. 47: 32-40. fa

A review of progress in Britain with various techniques of drainage, cultivation, and fertilizing of both peat bogs and heaths.

ZEHETMAYR, J. W. L. 698

1954 a Experiments in tree plantings on peat. Bull. For. Comm. Lond. 22. 110 pp. L

Manuring with phosphate is now an established practice on the poorer peats and full details of the experimental background to this technique are given. Phosphate is essential to the survival of all species other than pines on *Scirpus* peats, but even with pines growth rates may be more than doubled, so that application to all species is fully justified. On the *Molinia* and better peats phosphate is not necessary, while on intermediate types it is advisable to apply it to all species other than pines, to ensure survival and good early growth.

ZEHETMAYR, J. W. L. 699

1954 b Skogsgödsling i Storbritannien (Forest fertilization in Great Britain). Växt-närings-Nytt 10: 31-36. (Swedish)

ŽUKOV, A. B. 700

1950 (Agricultural technique in raising oak stands in Stalingrad, Astrakhan and Rostov Provinces). Les. Khoz. Lesoeksp. 3 (4): 16-17. (Russian) fa

A conference paper dealing chiefly with methods of improving dark to light chestnut soils of medium alkalinity and complexs of these soils with alkali soils proper, sufficiently for oak shelterbelt establishment. Two methods are briefly described: (1) Antipov-Karataev's, which consists in applying 2-3 metric tons/ha. of gypsum to the uncultivated soil in early spring, followed by ploughing to a depth of 27-30 cm. and loosening the compact horizon to a further 10-15 cm. with a subsoiler; applying and disking in another 2 tons/ha. of gypsum in the summer; and again ploughing and subsoil loosening to a total depth of 40-45 cm. in autumn. (2) Zemljanickiĭs, involving autumn ploughing and subsoil loosening to break up the compact horizon to a depth of 8-10 cm.; measures

for snow retention in the winter; a clean fallow in the following summer; application of 3-5 tons/ha. of gypsum in late August and early September; ploughing and loosening the subsoil once more to a depth in the latter of 10-12 cm.; applying 2-3 tons/ha. of gypsum and harrowing in early spring, and sowing a green-manure crop to be ploughed in when it flowers. Both of these methods are worth full-scale trials.

In 1950 the amount of mycorrhizal soil to be put in each seed plot was standarized by the Board of Shelterbelt Forestry at 60 g. for chernozems and dark chestnut soils, and 90 g. for chestnut and light chestnut soils. It is further recommended that each seed spot should be given 7-8 g. of granulated superphosphate.

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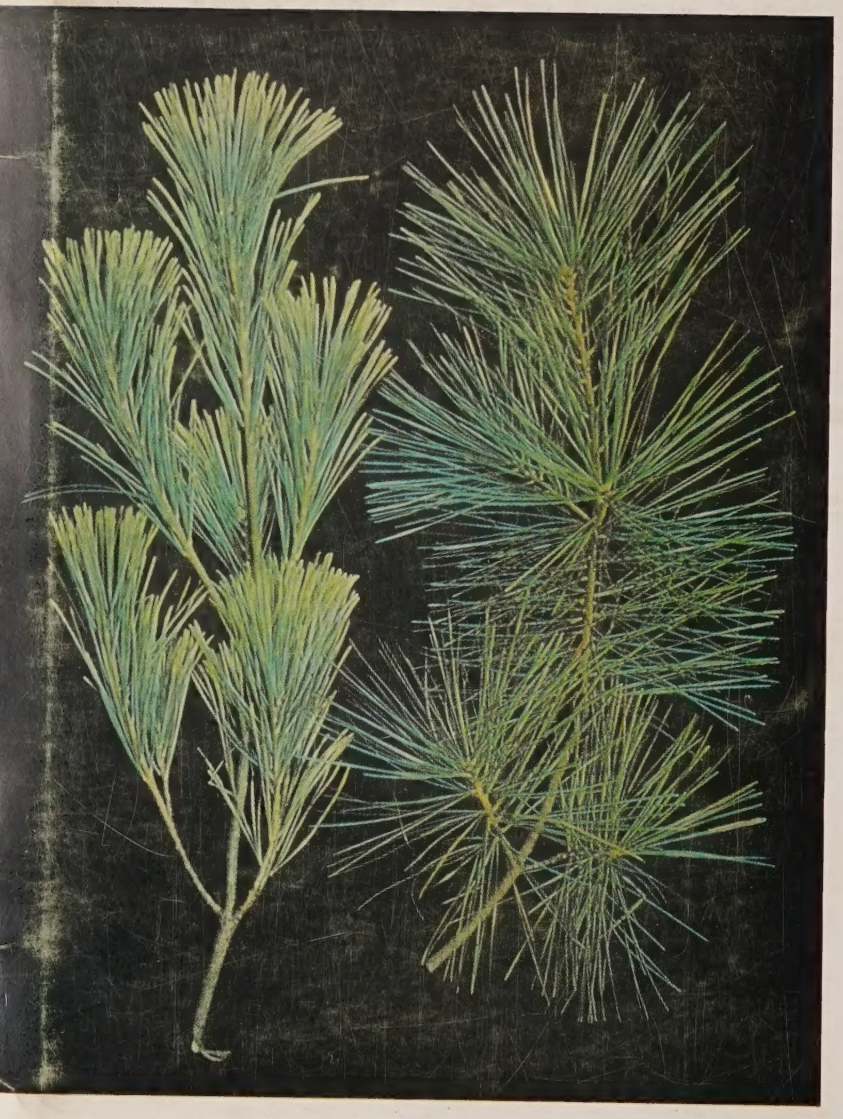

Magnesium deficiency contrasted with normal growth in white pine

Front cover: Potash recovery and deficiency in white spruce